

TECHNICAL INNOVATION

IN AMERICAN HISTORY

An Encyclopedia of Science and Technology



Rosanne Welch and Peg A. Lamphier, Editors

About the pagination of this eBook

This eBook contains a multi-volume set.

To navigate this eBook by page number, you will need to use the volume number and the page number, separated by a hyphen.

For example, to go to page 5 of volume 1, type "1-5" in the Go box at the bottom of the screen and click "Go."

To go to page 5 of volume 2, type "2-5" ... and so forth.

Technical Innovation in American History

Technical Innovation in American History

An Encyclopedia of Science and Technology

VOLUME ONE: COLONIAL AMERICA TO 1865

ROSANNE WELCH AND PEG A. LAMPHIER, EDITORS



An Imprint of ABC-CLIO, LLC
Santa Barbara, California • Denver, Colorado

Copyright © 2019 by ABC-CLIO, LLC

Every reasonable effort has been made to trace the owners of copyright materials in this book, but in some instances this has proven impossible. The editors and publishers will be glad to receive information leading to more complete acknowledgments in subsequent printings of the book and in the meantime extend their apologies for any omissions.

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, except for the inclusion of brief quotations in a review, without prior permission in writing from the publisher.

Library of Congress Cataloging-in-Publication Data

Names: Welch, Rosanne, author. | Lamphier, Peg A., author.

Title: Technical innovation in American history : an encyclopedia of science and technology / Rosanne Welch and Peg A. Lamphier, editors.

Description: Santa Barbara, California : ABC-CLIO, an Imprint of ABC-CLIO, LLC, 2019. | Includes bibliographical references.

Identifiers: LCCN 2018043489 (print) | LCCN 2018045557 (ebook) | ISBN 9781610690942 (ebook) | ISBN 9781610690935 (set) | ISBN 9781440847219 (volume 1) | ISBN 9781440847226 (volume 2) | ISBN 9781440847233 (volume 3)

Subjects: LCSH: Technological innovations—United States—History—Encyclopedias.

Classification: LCC T21 (ebook) | LCC T21 .T37 2019 (print) | DDC 609.73/03—dc23

LC record available at <https://lcn.loc.gov/2018043489>

ISBN: 978-1-61069-093-5 (set)
978-1-4408-4721-9 (vol. 1)
978-1-4408-4722-6 (vol. 2)
978-1-4408-4723-3 (vol. 3)
978-1-61069-094-2 (ebook)

23 22 21 20 19 1 2 3 4 5

This book is also available as an eBook.

ABC-CLIO

An Imprint of ABC-CLIO, LLC

ABC-CLIO, LLC

147 Castilian Drive

Santa Barbara, California 93117

www.abc-clio.com

This book is printed on acid-free paper 

Manufactured in the United States of America

Contents

VOLUME 1: COLONIAL AMERICA TO 1865

Introduction, xxi

Chronology, xxvii

Section 1: Colonial America and Enlightenment Science, 1

Overview, 1

American Philosophical Society, 8

Primary Document: Memorial of the American Philosophical Society Favoring an Exploration of the Alaskan Coast (1868), 10

Astronomical Almanacs, 11

Primary Document: Aphorisms from *Poor Richard's Almanack* (1732–1758), 13

Banneker, Benjamin (1731–1806), 13

Primary Document: Letter of Thomas Jefferson to Benjamin Banneker, Expressing Jefferson's Belief That Blacks Had Talents Equal to Other Races (1791), 14

Primary Document: Frontispiece of Benjamin Banneker's *Pennsylvania, Delaware, Maryland and Virginia Almanack and Ephemeris* (1792), 15

Bifocals, 16

Primary Document: Benjamin Franklin's Letter Describing His Invention of Bifocals (1725), 17

Bushnell, David (1740–c. 1824), 17

Primary Document: Engraving of David Bushnell's *American Turtle* (1775), 18

Colden, Jane (1724–1766), 19

Daylight Saving Time, 20

Extension Arm (Long Arm), 21

Fire Safety, 21

Flexible Catheter, 22

Food Production, Native American, 23

Franklin, Benjamin (1706–1790), 25

Primary Document: Letter of Benjamin Franklin Describing His Experiments with Electricity (c. 1750), 26

Franklin Stove, 27

Primary Document: Excerpt from Benjamin Franklin's *An Account of the New Invented Pennsylvanian Fire-Places* (1744), 28

Glass Harmonica (Armonica), 30

Primary Document: Excerpt of Benjamin Franklin's Letter to Father Giambatista Beccaria Describing the Glass Harmonica (1762), 32

Glover, Elizabeth (d. 1643), 32

Godfrey, Thomas (1704–1749), 33

Iron- and Silversmithing, 34

Kentucky Long Rifle, 35

Lightning Rod, 36

Primary Document: Frontispiece and Title Page of Benjamin Franklin’s *Experiments and Observations on Electricity* (1774), 37

Loom, 38

Primary Document: Excerpts from the Diary of Martha Ballard Describing Home Weaving (1787), 39

Lucas, Eliza (1722–1793), 40

Primary Document: Letter of Eliza Lucas to Her Father (1741), 41

Masters, Sybilla (c. 1675–1720), 42

Mather, Cotton (1663–1728), 43

Natural History, 44

Onesimus (fl. 1706–1716), 46

Peale, Charles Willson (1741–1827), 47

Primary Document: Letter of Charles Willson Peale to Thomas Jefferson Regarding New Agricultural Inventions and Innovations (1815), 48

Priestley, Joseph (1733–1804), 51

Rittenhouse, David (1732–1796), 52

Primary Document: Letter of Thomas Jefferson to David Rittenhouse (1778), 53

“Saugus Pot,” 54

Schooner, 55

Smallpox Inoculation, 56

Primary Document: George Washington’s Order for All Soldiers to Receive a Smallpox Inoculation (1778) and Letter of Edward Rowse to Thomas Jefferson Suggesting the Possibility of Vaccines for Other Diseases (1805), 58

Spinning Wheel, 59

Primary Document: An “Address to the Ladies” Urging American Women to Boycott British Goods (1767), 61

Street Lighting, 62

Swim Fins, 62

Three-Wheel Clock, 63

Primary Document: James Ferguson’s Description of Benjamin Franklin’s Three-Wheel Clock (1773), 64

Turtle Submarine, 65

Primary Document: Letter of David Bushnell to Thomas Jefferson Regarding Bushnell’s Experiments with Submarines (1787), 66

Whiton, David Erskine (1825–1904), 67

Winthrop, John (1714–1779), 68

Primary Document: John Winthrop Describes His Observation of the Planet Venus (1761), 69

Section 2: The New Republic and the Market Economy (1780–1820), 71

Overview, 71

Amphibious Steam Vehicle, 79

Primary Document: Image of an Amphibious Steam Vehicle (1834), 81

Apple Parers, 82

Primary Document: Apple Parer Patent Document Image (1836), 83

Babbitt, Sarah “Tabitha” (1779–1853), 84

Ballard, Martha (1735–1812), 84

Banjo Clock, 87

Blackwell, Elizabeth (1821–1910), 87

Primary Document: Excerpts from “Address on the Medical Education of Women” by Elizabeth and Emily Blackwell (1863), 89

Burr Truss Bridge, 91

Canals, 92

Canning Factory, 95

Charting the Gulf Stream, 96

Circular Saw, 97

Coffee Percolator, 98

- Cotton Gin, 99
- Cotton Sewing Thread, 101
- Dental Floss, 102
- Diffraction Grating, 103
- Erie Canal, 104
 - Primary Document: Letter of Robert Fulton to George Washington Urging Him to Support the Construction of Canals (1797), 106
- Evans, Oliver (1755–1819), 107
 - Primary Document: Letters from Oliver Evans to Thomas Jefferson (1804, 1808), 108
- Fire Hydrant, 109
 - Primary Document: Account of the Detroit Fire (1805), 110
- Fitch, John (1743–1798), 111
- Flatboat, 112
- Fulton, Robert (1765–1815), 114
- Gas Tungsten Arc Welding, 115
- Greene, Catharine Littlefield (1755–1814), 116
- High-Pressure Steam Engine, 117
- Interchangeable Parts, 118
- Internal Combustion Engine, 119
- Jefferson, Thomas (1743–1826), 121
- Lewis and Clark Expedition (1804–1806), 123
 - Primary Document: Excerpts from the Journal of the Lewis and Clark Expedition (1805, 1806), 126
- Lobster Trap, 127
- Lowell Mill System, 128
 - Primary Document: Description of the Life of a Mill Girl from the Lowell Offering (1845), 129
- Milling Machine, 130
- Morey, Samuel (1762–1843), 131
- Multitubular Boiler, 132
- National Road, 132
- Odometer, 135
- Patent and Copyright Statutes, 135
- Practical Ocean Navigation, 137
- Report on Manufactures* (1791), 138
- River Steamer, 139
- Rumford Fireplace, 141
- Rush, Benjamin (1746–1813), 142
 - Primary Document: Excerpt from the Medical Writings of Benjamin Rush (1805), 144
- Screw-Cutting Lathe, 145
- Slater, Samuel (1768–1835), 146
- Steam Engine, 148
- Steam Tractor, 149
- Steamboat, 150
 - Primary Document: Newspaper Announcement of Robert Fulton’s Steamboat (1807) and Charles Dickens’s Account of His Ride on an American Steamboat (1842), 153
- Submarine, 154
- Suspension Bridge, 155
- Swivel Chair, 157
- Thompson, Benjamin (Count Rumford) (1753–1814), 158
- Three-Piece Iron Plow, 159
 - Primary Document: Petition to Congress Asking for a Renewal of the Patent on Jethro Wood’s Cast-Iron Plow (1846), 160
- Vapor-Compression Refrigerator, 161
- Waltham-Lowell Textile System, 161
- Wheel Cipher, 162
 - Primary Document: Excerpts from Thomas Jefferson’s Notes on the Wheel Cipher (Undated), 163
- Whitney, Eli (1765–1825), 163
 - Primary Document: Letter of Eli Whitney to His Father Regarding the Ginning of Cotton (1793), 165

Section 3: Antebellum Industrialization and the Civil War (1820–1865), 167

Overview, 167

Adhesive Tape, 174

Agassiz, Louis (1807–1873), 175

Primary Document: Excerpt from the Journal of Louis Agassiz Describing a Trip to the United States (1846), 176

Anesthesia, 178

Ball Bearings and Babbitt Metal, 179

Best Friend Steam Engine, 181

Breast Pump, 182

Brown Truss, 182

Burglar Alarm, 183

Calliope (Steam Organ), 183

Cannon, Double-Barrel, 185

Primary Document: Excerpt from the Memoirs of Former Confederate General Edward Porter Alexander on “Artillery Hell” at Antietam (1907), 186

Civil War Medicine (1861–1865), 186

Primary Document: Report of Medical Director Robert Murray on Union Casualties Suffered at the Battle of Shiloh (1862), 188

Civil War Nursing, 190

Primary Document: Clara Barton’s Poem “The Women Who Went to the Field” (1892), 192

Clipper Ship, 194

Primary Document: Excerpts from the Journal of Alexander Van Valen Describing His Journey to California via Clipper Ship (1849), 196

Clothespin, 196

Coal-Mining Technologies, 197

Coil Magnet/Electromagnet, 199

Colgate, William (1783–1857), 200

Colored Female Free Produce Society, 201

Colt, Samuel (1814–1862), 202

Colt Revolver, 203

Columbiad Cannon, 204

Combine Harvester, 205

Compact Iron Stove, 207

Conestoga Wagon, 208

Primary Document: Excerpt from John G. Abbott’s Recollections of Traveling to California by Wagon Train (1852), 210

Corn Sheller, 211

Corset, 211

Coston, Martha (1826–1904), 213

Cowboy Hat (Stetson), 213

Crumpler, Rebecca (1831–1895), 214

Cylinder Pin Tumbler Lock, 216

Dahlgren Gun, 216

Deere, John (1804–1886) and Deere and Company, 217

Dental Chair, 219

Detachable Collar, 219

Dix, Dorothea (1802–1887), 220

Dustpan, 221

Eggbeater, 222

Electric Doorbell, 223

Electric Stove, 223

Electric Street Railway, 223

Elevator Safety Brake, 224

Equatorial Sextant, 225

Field, Cyrus West (1819–1892), 226

Fire Alarm Call Box, 227

Floating Dry Dock (1849), 228

Primary Document: Excerpt from Abraham Lincoln’s Patent Application for the Floating Dry Dock (1849), 229

Gas Well, 230

Gold-Mining Technologies, 231

Goodyear, Charles (1800–1860), 232

- Grain Elevator, 233
- Gridiron for Cooking, 234
- Hand-Cranked Ice Cream Maker, 234
- Health Reform, 235
- Henry, Joseph (1797–1878), 237
- Hoop Skirt, 238
- Horse-Drawn Streetcar, 239
 - Primary Document: Image of a Horse-Drawn Streetcar (c. 1920), 240
- Hospital Transport Service, Women’s Department, 240
- Howe, Elias (1819–1867), 241
- Howe Truss, 242
- Interchangeable Gun Parts, 243
- Inverted Microscope, 244
- Jervis, John B. (1795–1885), 245
- Land Mines, 245
- Long, Crawford Williamson (1815–1878), 246
- Machine/Gatling Gun, 247
- Mason Jar, 249
- Maynard, Edward (1813–1891), 249
- Maynard Carbine, 250
- McCormick, Cyrus (1809–1884), 252
 - Primary Document: Letter of Robert E. Lee to Cyrus McCormick Regarding the Curriculum at Washington College (1865), 253
- Mechanical Reaper, 254
- Merrick, Solymon (1806–1852), 255
- Military Technology (Civil War), 255
- Mitchell, Maria (1818–1889), 258
- Morse, Samuel F. B. (1791–1872), 260
- Morse Code, 261
- National Academy of Sciences (NAS), 262
- Nightingale Plan, 263
- North, Simeon (1765–1852), 264
- Omnibus System, 265
- Papermaking Machine, 266
- Pencil Eraser, 267
- Pepper (and Salt) Shaker, 267
- Perkins, Jacob (1766–1849), 267
- Platform Scale, 268
- Polished Steel Plow, 269
- Printing, 269
- Printing Telegraph, 271
- Pullman, George Mortimer (1831–1897), 273
- Railroad T-Rail and Tie, 273
- Railroads, 274
 - Primary Document: Pacific Railway Act (1862), 276
- Ratchet Wrench, 279
- Relay, 280
- Repeating Rifle, 280
- Roller Skates, 282
- Rotary Hook (for Sewing Machines), 283
- Rucker Ambulance, 283
- Safety Pin, 284
- Sewing Machine, Automated, 284
- Sewing Pattern, 286
- Solar Compass, 287
- Spar Torpedo, 288
- Steam Locomotive, 288
- Steam Shovel, 291
- Stevens, Robert Livingston (1787–1856), 292
- Strauss, Levi (1829–1902), 294
- Telegraph, 294
 - Primary Document: Act Authorizing Construction of a Transcontinental Telegraph (1855), 297
- Ten-Hour Movement, 297
 - Primary Document: Excerpt from the Preamble and Constitution of the Lowell Female Labor Reform Association (1846), 298
- Toothpaste, 299

Torpedo, 301
 Transatlantic Cable, 302
 Transverse Shuttle, 303
 Twine Knotter, 304
 Twist Drill, 304
 United States Capitol Building, Construction of, 304
 U.S. Sanitary Commission (USSC), 306

Vulcanization, 307
 Walker, Mary (1832–1919), 308
 Western Union Telegraph Company, 310
 Zipper, 311
Bibliography: Colonial America to 1865, 313
Index, 317

VOLUME 2: RECONSTRUCTION THROUGH WORLD WAR II

Section 1: The Rise of Industrialism, Reconstruction, and the Gilded Age (1866–1900), 1

Overview, 1

Abbe, Cleveland (1838–1916), 7

AC Generator and Transformer, 9

Primary Document: American Institute of
 Electrical Engineers (AIEE) Member
 Biography for William Stanley (1934), 10

AC Induction Motor, 10

Primary Document: Nikola Tesla's Patent for an
 AC Induction Motor (1896), 11

Adding Machine with Keys, 14

Amalgamated Clothing Workers of America
 (ACWA), 14

American Telephone and Telegraph Company
 (AT&T), 16

Asphalt, 17

Aspirin, 18

Barbed Wire, 19

Primary Document: Excerpts from an Article on
 Joseph F. Glidden and the Barb-Wire
 Industry (1884), 21

Batteries, 23

Bee Smoker, 24

Primary Document: Excerpt on the Use of a Bee
 Smoker from Moses Quinby's *Mysteries of
 Bee-Keeping Explained* (1853), 24

Bell, Alexander Graham (1847–1922), 26

Primary Document: Letter of Alexander Graham
 Bell to His Parents Describing His Idea for
 the Telephone (1874), 27

Berliner, Emile (1851–1929), 29

Brooklyn Bridge, 30

Camera, 31

Can Opener, 33

Carnegie, Andrew (1836–1919), 34

Carnegie Steel Mill, 35

Primary Document: Correspondence of Andrew
 Carnegie and Henry Clay Frick Regarding
 the Homestead Strike (1892), 37

Carpet Sweeper, 38

Carver, George Washington (1861–1943), 38

Primary Document: George Washington Carver
 Addresses Congress (1921), 41

Cash Register, 42

Celluloid, 42

Coca-Cola, 43

Cotton Candy Machine, 45

Crayons, 45

Curling Iron, 47

Diner (Horse-Drawn), 47

Dishwashing Machine, 48

Dow Chemical Company, 49

- du Pont, Pierre (1870–1954), 50
- DuPont Company, 52
- Duprey, Ana Roqué de (1853–1933), 54
- Duryea, Charles (1861–1938) and Frank (1869–1967), 54
- Earmuffs, 55
- Eastman, George (1854–1932), 56
- Eastman Kodak Company, 56
- Edison, Thomas (1847–1931), 57
- Electric Iron, 59
- Electric Lightbulb, 60
- Electricity, War of the Currents, 61
- Electrification, Urban, 63
- Escalator, 65
- Ferris Wheel, 66
 - Primary Document: Telegrams between Luther Rice and George Ferris Following the Successful Test of the Ferris Wheel (1893), 68
- Folding Cabinet Bed, 68
 - Primary Document: Patent for Folding Cabinet Bed (1885), 69
- Food Preservation, 70
- Fountain Pen, 71
- Frasch Process, 72
- Gas Transmission, 73
- General Electric, 74
- Goodrich, B. F. (1841–1888), 75
- Goodyear, Charles, Jr. (1833–1896), 76
- Hallidie, Andrew Smith (1836–1900), 76
- Harvard Computers, 77
 - Primary Document: Undated Photo of the Harvard Computers, 79
- Haynes, Elwood (1857–1925), 79
- Heyl, Henry (1842–1919), 80
- Ice Cream Soda, 81
- Inman, George (1895–1972), 82
- Iron Ship with Revolving Turret, 83
- Ironing Board, 83
- Jeans, 84
- Jockstrap, 86
- Jones, Amanda T. (1835–1914), 86
 - Primary Document: “The Soldier’s Mother” by Amanda T. Jones (1867), 87
- Kellogg, William Keith (1860–1951), 88
- Kelly, William (1811–1888), 89
- Kier, Samuel (1813–1874), 90
- Kinematoscope, 91
- Knight, Margaret (1838–1914), 91
- Lady Stitchers’ Union, 92
- Lawn Mower, Reel-Type, 93
- Lennox, David (1855–1947), 93
- Linotype Machine, 94
- Margarine, 95
- Matchbook Matches, 96
- Matzeliger, Jan Ernst (1852–1889), 96
- Maxim, Hudson (1853–1927), 97
- Metal Detector, 97
- Metal Electrode Weld, 98
- Metal Windmill, 99
- Military Technology (Post–Civil War through World War I), 100
- Motion Picture Camera, 102
- National Consumers League, 104
- National Institutes of Health (NIH), 105
- Niagara Falls Power Plant, 106
 - Primary Document: Excerpt from Nikola Tesla’s Commemoration Address for the Niagara Falls Power Plant (1897), 108

Office Technology (Pre–World War II), 112

Paper Bag, 114

Paper Clip, 114

Phonograph, 115

Primary Document: Roll Call of Companies at
the Phonograph Convention in Chicago
(1890), 119

Photographic Film, 120

Pipe Wrench, 121

Player Piano, 121

Portland Cement Mortar, 122

Punch Card Tabulator, 123

Quadruplex Telegraph, 124

Railroad Refrigerator Car, 125

Railroad Sleeping Car and Pullman Car, 126

Railroad Switch Systems, 127

Richards, Ellen Swallow (1842–1911), 128

Roebing, Emily (1843–1903), 129

Primary Document: Photograph of the Promenade
on the Brooklyn Bridge (1899), 131

Roebing, John (1806–1869), 131

Roll Film, 133

Roller Coaster, 133

Rotary Washing Machine, 134

Rowing Machine, 135

Saccharine, 135

Silo, 137

Skyscraper, 138

Soda Fountain, 140

Spork, 141

Steel Arched Bridge, 142

Stethoscope, Binaural, 143

Stockyards, 144

Primary Document: Photograph of Chicago’s
Union Stock Yards (1907), 145

Tape Measure, 146

Taylor, Frederick (1856–1915), 146

Tesla, Nikola (1856–1943), 147

Ticker Tape, 149

Tom Thumb Locomotive, 150

Primary Document: John Latrobe’s Description
of the *Tom Thumb* Locomotive (1830), 150

Track-Type Tractor, 152

Transcontinental Railroad, 153

Twine Self-Binding Harvester, 155

Typewriter and QWERTY, 155

Velocipede, 156

Vending Machine, 157

Vibrator, 158

Water Heater, 159

Westinghouse Air Brake, 160

World’s Fairs, 161

Wright, Wilbur (1867–1912) and Orville
(1871–1948), 164

Primary Document: Entry from Orville Wright’s
Diary of December 17, 1903, 166

Yerkes Observatory, 166

Section 2: The Progressive Era and the Roaring Twenties (1900–1929), 169

Overview, 169

Aerosol Spray Can, 176

Airplane, 176

Anderson, Mary (1866–1953), 179

Assembly Line, 179

Primary Document: Excerpt from Henry Ford’s
“The First Assembly Line” (1913), 181

Automobile Technologies (Pre–World War II), 181

Bakelite, 183

Band-Aid, 185

Bell Telephone Laboratories, 185

- Binney & Smith Inc., 186
- Birdseye, Clarence (1886–1956), 187
- Blender, 188
- Blodgett, Katherine (1898–1979), 188
- Boeing, William E. (1881–1956), 189
- Bottle-Making Machine, 190
- Bread Slicer and Wrapping Machine, 191
- Bryant, Alice (1862–1942), 192
- Cannon, Annie Jump (1863–1941), 192
- Carothers, Wallace (1896–1937), 194
- Christmas Tree Lights, 194
- Chuck Wagon, 195
- de Forest, Lee (1873–1961), 196
- Dickelman, Elizabeth (dates unknown), 197
- Dickerson, Mary Cynthia (1866–1923), 197
- Drew, Charles (1904–1950), 198
- Ductile Tungsten, 199
- Einstein, Albert (1879–1955), 199
- Empire State Building, 201
- Ford, Henry (1863–1947), 202
- Freon, 204
- Galvin, Paul Vincent (1895–1959), 205
- General Motors (GM), 206
- Gilbreth, Lillian (1878–1972), 208
- Gramophone/Victrola, 208
- Gumball Machine, 210
- Hewitt, Peter C. (1861–1921), 210
- Hoosier Cabinet, 212
- Hydroelectric Power, 212
- Jacob, Mary Phelps (1891–1970), 214
- Kettering, Charles F. (1876–1958), 215
- Lie Detector, 216
- Life Savers Candy, 217
- Marsh, Albert L. (1877–1944), 217
- McKnight, William L. (1887–1978), 218
- Midgley, Thomas (1889–1944), 219
- Morgan, Garrett (1877–1963), 220
- Motorcycle (Pre–World War II), 221
- National Advisory Committee for Aeronautics (NACA), 223
- Noether, Amalie Emmy (1882–1935), 224
- Olds, Ransom Eli (1864–1950), 225
- Panama Canal, 225
- Primary Document: Excerpt from President Theodore Roosevelt’s Message to Congress After Returning from the Canal Zone in Panama (1906), 228
- Pennington, Mary Engle (1872–1952), 232
- Petroleum Industry (Pre–World War II), 233
- Pop-Up Toaster, 234
- Pushpin, 235
- Radio, 236
- Primary Document: “Radio’s Real Uses” by E. E. Free, Science Editor for *The Forum* (1926), 239
- Rocky Mountain Laboratories, 240
- Safety Razor, 240
- Scotch Tape, 241
- Subway System of New York City, 242
- Talking Movies, 243
- Traffic Light, Electric, 245
- Triode Tube, 246
- Turbine Engine, Gas Powered, 247
- Washing Machine, Electric, 247
- Welding, Alternating Current, 248
- Welding, Automatic, 249

Section 3: The Great Depression and World War II (1930–1945), 251

Overview, 251

Alaska Highway, 257

Primary Document: Excerpt from Ruth Gruber’s Study of Highway Routes to Alaska (1941), 259

Atomic Bombs/Nuclear Weapons, 260

Avenger Field, 261

Primary Document: Letters of Mary Anna Martin Wyall, a Pilot Trainee at Avenger Airfield (1944), 262

B-17 Flying Fortress, 263

Big Science, 264

Blood Transfusion, 265

Bradberry, Henrietta (1903–1979), 266

Calutron Girls, 267

Clarke, Edith (1883–1959), 268

Curtiss-Wright Aeronautical Engineering Cadettes, 269

D Rations, 270

Electric Guitar, 270

Fermi, Enrico (1901–1954), 271

FM Radio, 272

Freeze-Dried Food, 273

Garbage Disposal, 273

Gas Mask, 274

Golden Gate Bridge, 274

Primary Document: Letter of Charles Ellis to the *San Francisco Chronicle* Regarding the Golden Gate Bridge (1930), 275

Helicopter, 276

Hoover Dam, 277

Primary Document: President Franklin D. Roosevelt’s Speech at the Dedication of Hoover Dam (1935), 280

Hydrogen Bomb, 283

Hydroponics, 284

International Ladies’ Garment Workers’ Union (ILGWU), 285

Primary Document: “The Uprising of the 20,000,” 286

Interstate Highway System, 287

Primary Document: Excerpt from the Federal-Aid Highway Act (1956), 289

Lamarr, Hedy (1914–2000), 290

Primary Document: Patent for Hedy Lamarr’s Frequency-Hopping System (1942), 292

Lange, Dorothea (1895–1965), 292

Lend-Lease Program (1941–1945), 293

Liberty Ships, 294

M&M’s, 295

M4 Sherman Tank, 295

Manhattan Project, 296

Mead, Margaret (1901–1978), 297

Microwave Oven, 299

Military Technology (World War II), 299

MIT Radiation Laboratory, 301

Neoprene, 302

Oppenheimer, J. Robert (1904–1967), 303

Paul, Les (1915–2009), 304

Penicillin, 306

pH Meter, 307

Photocopier, 307

Pinball and Arcade Games, 308

Plastic Wrap, 309

Radar, 309

Refrigerator, 310

Richter Scale, 311

Rocketry (Pre–Space Age), 311

Rosie the Riveter, 313

- Primary Document: Excerpt from Interview with Maria Isabel Solis (2003), 315
- Schwinger, Julian (1918–1994), 316
- Semple, Ellen Churchill (1863–1932), 317
- SONAR, 318
- Submarine Technology, 319
- Tampon, 320
- Tea Bag, 321
- Telephone, 322
- Television, 325
- Tennessee Valley Authority Electricity Project (TVA), 328
- Thomas, Vivien Theodore (1910–1985), 329
- Tizard Mission, 331
- Women’s Airforce Service Pilots (WASPs), 331
- Wu, Chien-Shiung (1912–1997), 333
- Bibliography: Reconstruction through World War II*, 335
- Index*, 339

VOLUME 3: THE COLD WAR TO THE PRESENT

Section 1: The Cold War (1946–1979), 1

- Overview*, 1
- 911 Emergency System, 8
- Agent Orange, 9
- “Air” Athletic Shoes, 11
- Antiballistic Missiles (ABMs), 11
- Antibiotic, 13
- Apollo Project, 14
- ARPANET, 16
- Aspartame, 18
- Association for Women in Mathematics (AWM), 19
- Atari, 20
- Automotive Technologies (Post–World War II), 22
- Baer, Ralph (1922–2014), 24
- Primary Document: Excerpt from Ralph Baer’s Four-Page Paper Describing His Plans for Simple Video Games (1966), 25
- Bar Code Scanner, 25
- Benerito, Ruth Rogan (1916–2013), 27
- Biodiesel, 27
- Primary Document: Statement of Anne Steckel, the Vice President of Federal Affairs of the National Biodiesel Board, to the Senate Committee on Environment and Public Works (2016), 29
- Birth Control Pill, 31
- Bomb Disposal Robots/Units, 33
- Brill, Yvonne Madalaine Claeys (1924–2013), 34
- Primary Document: Yvonne Brill’s Patent for New Jet Propulsion Technology (1974), 35
- Brown, Marie Van Brittan (1922–1999), 35
- Bulletproof Vest/Kevlar, 36
- Carson, Rachel (1907–1964), 36
- Chlorofluorocarbons (CFCs), 38
- Climate Change, 39
- CO₂ Welding, 41
- Commodore 64, 42
- Comsat/Intelsat, 42
- Curanderas*, 43
- Dark Matter Science, 45
- Dolby Laboratories, 47
- Drones, 48
- Electric Car, 49
- Primary Document: Article from the energy.gov Web Site on Electric Cars (2014), 50
- Enders, John Franklin (1897–1985), 54
- Engelbart, Douglas (1925–2013), 55

- ENIAC and the “ENIAC Girls,” 55
- Fortran, 56
- Fuller, Richard Buckminster (1895–1983), 57
 - Primary Document: Drawing of R. Buckminster Fuller’s Geodesic Dome (c. 1933), 58
- Global Positioning System (GPS), 59
- Goeppert-Mayer, Maria (1906–1972), 60
- Graham, Bette (1924–1980), 61
- Hamilton, Margaret (1936–), 62
- Haynes, Martha Euphemia Lofton (1890–1980), 63
- Hopper, Grace (1906–1992), 65
- Hydraulic Fracturing (“Fracking”), 66
- Hydrogen Energy, 67
- IBM 360 Computer, 68
- In Vitro Fertilization (IVF), 70
- Integrated Circuit, 70
- Intel Corporation, 71
- Jackson, Mary Winston (1921–2005), 72
- Jet Propulsion Laboratory (JPL), 74
- Johnson, Katherine Goble (1918–), 75
- Kilby, Jack (1923–2005), 76
- Kwilek, Stephanie Louise (1923–2014), 77
- Lacks, Henrietta (1920–1951), 78
- Land, Edwin H. (1909–1991), 79
- Lasers, 80
- LED Lights, 81
- Liquefied Natural Gas (LNG) Carrier, 82
- Liskov, Barbara (1939–), 82
- M16 Rifle, 83
- Magnetic Resonance Imaging (MRI), 84
- MASER, 85
- McClintock, Barbara (1902–1992), 86
- Mercury 13, 88
- Military-Industrial Complex, 88
- Minsky, Marvin (1927–2016), 90
- Moog, Robert (1934–2005), 91
- Morgan, Mary Sherman (1921–2004), 92
- Nanotechnology, 93
- Napalm, 94
- National Aeronautics and Space Administration (NASA), 94
 - Primary Document: Letter of President Dwight Eisenhower to Keith Glennan, Retiring Administrator for NASA (1960), 98
- National Science Foundation (NSF), 98
- Noyce, Robert (1927–1990), 99
 - Primary Document: Personal Interview with Robert Noyce for the IEEE History Center (1975), 100
- Nuclear and Radiation Accidents, 102
- Ochoa, Ellen (1958–), 105
- Orshansky, Mollie (1915–2006), 106
- Packet Switching, 107
- Particle Accelerator, 108
 - Primary Document: Press Release Issued by CERN, the European Organization for Nuclear Research (2012), 109
- Pauling, Linus “Carl” (1901–1994), 110
- Permanent Press Fabric, 111
- Petroleum Industry (Post–World War II), 112
- Plasma Arc Welding, 114
- Plastics, 115
- Polaroids, 117
- Polio Vaccine, 118
- Pong*, 119
- Portable Transistor Radio, 120
- Rocket Girls of JPL, 121

- Primary Document: Press Release Announcing Eleanor F. Helin's Naming to the Women in Science and Technology International (WITI) Hall of Fame (1998), 122
- Rogallo, Francis Melvin (1912–2009), 123
- Sabin, Albert B. (1906–1993), 124
- Salk, Jonas (1914–1995), 125
- Satellites and Space Probes, 126
- Sherman, Patsy O'Connell (1930–2008), 127
- Shippingport Atomic Power Station, 128
- Silent Spring* (1962), 129
- Silicon Valley, 130
- Single-Chip Microprocessor, 132
- Skylab, 133
- Skywalker Ranch, 134
- Smallpox, Eradication of, 135
- Smoke Detector, 136
- Primary Document: Chris P. Borreson's Account of the Iroquois Theater Fire (1904), 137
- Space Science and Technology, 137
- Primary Document: Account of Astronaut David Alexander Wolf Voting in Space (1997), 138
- Stealth Technologies, 138
- Superconductivity, 140
- Taussig, Helen (1898–1986), 141
- Telephone Switching, Computerized, 143
- Thomas, Valerie (1943–), 144
- Touch-Tone Phones, 145
- Trans-Alaska Pipeline, 145
- Primary Document: Bill to Reform the Trans-Alaska Pipeline System Authorization Act (1989), 146
- Transistor Radio, 148
- TV Dinner, 149
- Unimate/Industrial Robot, 150
- Universal Automatic Computer (UNIVAC), 150
- Vaccines, 151
- Vaughan, Dorothy (1910–2008), 153
- Vocoder, 155
- Voyager Spacecraft, 156
- Wise, Brownie (1913–1992), 157
- Xerox Corporation, 158
- Primary Document: Patent for Xerography (1956), 159
- Yalow, Rosalyn Sussman (1921–2011), 160
- Section 2: The Post–Cold War Era (1980–1999), 163**
- Overview*, 163
- AIDS Research, 171
- Primary Document: Introduction to the AIDS Archive by Former Surgeon General C. Everett Koop, 173
- Apple, 177
- Apple II, 179
- Artificial Heart, 180
- Artificial Intelligence (AI), 181
- Berners-Lee, Tim (1955–), 184
- Boston Tunnel, 185
- CD and DVD, 186
- CD-ROM, 188
- Computer/Information Technology, 189
- Cray, Seymour (1925–1996), 191
- Dell, Michael “Saul” (1965–), 192
- Digital Photography, 193
- Primary Document: Excerpt from the Patent for Kodak's Digital Camera (1978), 195
- Elion, Gertrude (1918–1999), 195
- Floppy Disk, 197
- Fossey, Dian (1932–1985), 198
- Gates, Bill (1955–), 199

Genetic Engineering, 201	Sustainable Agriculture, 240
Gosling, James (1955–), 204	Wind Energy, 242
IBM Personal Computer, 205	Wozniak, Steve (1950–), 244
Infant Formula, 206	
Insulin Pump, 207	Section 3: The New Millennium
Internet, 208	(2000–Present), 247
Jobs, Steve (1955–2011), 209	<i>Overview</i> , 247
Kare, Susan (1954–), 213	Airplane Deicer, 254
Laser Cataract Surgery Device, 213	Amazon Web Services, 255
Metcalf, Robert (1946–), 214	Amazon.com, 256
Microchip, 215	Artificial Memories, 258
Microsoft, 217	Bashen, Janet (1957–), 259
Mobile Phone, 218	Birth Control Patch, 260
Nuclear Energy/Nuclear Power Plants, 219	Blizzard Entertainment, 260
Open-Source Software, 221	Cancer Research, 261
Perlman, Radia (1951–), 222	Cassini Saturn Mission, 262
Personal Computer (PC), 223	Drake Equation, 264
Ride, Sally (1951–2012), 224	e-Book and e-Reader, 264
Ritchie, Dennis (1941–2011), 226	e-Sports, 267
Primary Document: Abstract for “The Development of the C Language” by Dennis Ritchie (1993), 227	Facebook, 268
Robotic Surgery, 229	Gene Patenting, 270
Primary Document: Letter from Elizabeth A. Kage, Acting District Director of the FDA, to Gary S. Guthart, President of Intuitive Surgical Inc., on the Regulation of Robotic Surgery (2013), 230	Genetically Modified Foods, 271
Satellite Radio, 232	Google, 274
Self-Driving Cars, 233	Google Earth, 275
SEMATECH, 234	Grandin, Temple (1947–), 276
Solar Energy, 235	Hawking, Stephen (1942–2018), 277
Space Shuttle, 237	Hubble Space Telescope, 278
Strategic Defense Initiative (SDI), 239	Human Genome Project, 279
	Hybrid Vehicles, 281
	Hypertext, 283
	International Space Station, 283
	Intraocular Contact Lens, 285
	iPod, 286

- Java, 287
 - Primary Document: Interview with James Gosling, the Creator of Java (2001), 288
- Jemison, Mae (1956–), 290
- Joystick/Flight Simulator, 291
- Kurzweil, Ray (1948–), 291
- Linux, 292
- Maker Faire, 293
- March for Science, 295
- Mars Rover Series, 295
- MIDI (Musical Instrument Digital Interface), 297
- Moore, Ann (1934–), 298
- MP3, 298
- Negroponte, Nicholas (1943–), 299
- Netscape, 300
- Nye, Bill (1955–), 302
- One Laptop per Child, 302
- PayPal, 303
- PGP Encryption, 303
- Quantum Science, 304
- RFID Labels, 305
- RU-486/Plan B, 307
- Science Friday*, 308
- SETI (Search for Extraterrestrial Intelligence), 308
- Smartphone and 3G Network, 311
- Tarter, Jill (1944–), 312
- Thompson, Ken (1943–), 313
 - Primary Document: Interview with Ken Thompson, Inventor of the UNIX System (2011), 314
- 3-D Printing, 316
- TOR (The Onion Router), 318
- Torvalds, Linus (1969–), 318
- Tyson, Neil deGrasse (1958–), 319
- Video Game, 321
- Video Streaming Services, 323
- Virtual Reality (VR), 323
- Wang, An (1920–1990), 325
- Williams, Roberta (1953–) and Ken (1954–), 327
- Wireless Communication, 328
- YouTube, 330
- Bibliography: The Cold War to the Present*, 331
- Editors and Contributors*, 335
- Index*, 345

Introduction

Technological Innovation in American History: An Encyclopedia of Science and Technology comprises three chronologically arranged volumes. Each of the three volumes is divided into three chronological sections, and each section begins with an introductory essay followed by a mix of entries and primary document excerpts that cover topics and people characteristic of the period. Together, the three volumes contain over 700 entries and 91 primary document selections.

For many entries, it was difficult to know whether the inventor/innovator or the invention/innovation should take the lead. The editors made a decision based on the relative significance of the invention/innovation as compared to the multiplicity of the inventor/innovator's work. A person who invented a number of items received an entry in his or her name, while a person who invented one significant object lost out to the object. Some of the most majorly productive American inventors/innovators, such as Benjamin Franklin, Thomas Edison, and Steve Jobs, have both biographical entries and entries on their numerous contributions to American science and technology.

Also, some obscure inventions/innovations and persons are included in the encyclopedia so as to widen its scope and include persons not generally included in such a collection. The editors endeavored to be inclusive so as to introduce readers to a wider spectrum of the national experience. Some might dismiss this inclusiveness as weak-minded political correctness, but we argue that "correctness" is not a vice. Rather, it is a significant American and human value and one worth honoring.

In most cases, the entry writers and editors chose traditional sources for an entry's Further Reading

bibliography and the general bibliographies for each volume, not to privilege print sources but because most readers need little help finding electronic sources. Nonetheless, the 21st century has given professional historians and writers an invaluable ocean of information worth sharing with students and general readers who are the core audience of this work.

The "See also" cross-references at the end of each entry are not meant to be complete. Rather, they function as a guide to lead the reader to other entries that might be of interest. We say "might" because no editor, no matter how skilled, can foresee how a reader will use an entry or what material in an entry will prove the most useful. Cross-referenced entries at the start of a "See also" reference are for other entries in the same volume and section being consulted; cross-referenced entries in other areas of the encyclopedia then follow and are marked with the volume and section information to make finding them easier and more efficient.

ORGANIZATION

Technological Innovation in American History is divided chronologically into the following sections.

Volume 1: Colonial America to 1865

Section 1: Colonial America and Enlightenment Science

Covering inventors and innovations from the 17th century to about 1780, this section explores the earliest days of American science and technology. Colonial and Revolutionary Americans did not have the educational or institutional infrastructure in place to

create a notable culture of innovation, particularly when compared to most European countries. The realities of colonial life meant that Euro-Americans worried more about basic survival than they did progress in science, or what they called “natural philosophy.” Indigenous people had long-standing traditions in medical science, agricultural technologies, and metalworking, but by and large, colonial Americans dismissed these technologies as “primitive” and beneath notice.

Benjamin Franklin was colonial America’s most prolific and significant scientist and inventor. Franklin engaged in groundbreaking studies in electricity that led to his invention of the lightning rod and a static-electricity generator. He also invented swim fins, bifocals, a musical instrument called the glass harmonica, an improved urinary catheter, and the Franklin stove. In the true spirit of collaboration and scientific openness, Franklin never patented his inventions, believing as he did that innovation could only grow if shared. Franklin also cofounded the American Philosophical Society in 1743. That institution continues to promote American scientific research.

Revolutionary-era astronomer David Rittenhouse built the nation’s first significant telescopes and a number of navigational mechanisms.

Section 2: The New Republic and the Market Economy (1780–1820)

After the conclusion of the American Revolution in 1783, the United States began a process of gradual westward expansion. This expansion both encouraged and produced a number of scientific discoveries and technological innovations. When not engaged in politics, Thomas Jefferson was an enthusiastic proponent of American science and an inventor himself. Among his inventions were an improved swivel chair, a dumbwaiter for wine, the revolving bookcase, and a wheel cipher for sending coded messages that he never built and that was reinvented by the American military in the early 20th century.

Jefferson also promoted the now famous Lewis and Clark Expedition, which explored the North American west from 1804 to 1806. Although the expedition’s primary mission was to discover the

“Northwest Passage,” a waterway leading from the Missouri River to the Pacific Ocean, the explorers were also tasked with creating a record of western wildlife and plant life. Though the Northwest Passage proved nonexistent, the 5,000 pages of journals authored by Meriwether Lewis and William Clark continue to provide scholars with a wealth of information about the flora, fauna, and indigenous peoples of the intermountain west.

Improvements in steam power led to a wealth of steam-powered mechanisms, from steamboats to steam tractors. Steam power provided American farmers and industrialists with an affordable and relatively rapid way to move goods about the country.

Canal building, culminating in the massive Erie Canal project in New York, pushed trans-Appalachian expansion. Begun in 1817 and completed in 1825, the Erie Canal crossed 350 miles between the Hudson River and the Great Lakes. The canal proved an almost immediate economic success, because in providing a link between the East Coast and the Great Lakes, it opened markets in northern Ohio, Illinois, and Indiana.

Section 3: Antebellum Industrialization and the Civil War (1820–1865)

American technological innovation exploded during the decades before the American Civil War (1861–1865), so much so that the era is often referred to as the Industrial Revolution.

Railroads proved an even greater boon to the American economy than did canals. Improvements in steel production and steam technology allowed a plethora of railroad companies to spring up in every state, fundamentally changing the way people and goods moved through the country. The telegraph proved a significant change in the way Americans communicated, allowing near-instantaneous communication over long distances for the first time in world history.

In 1847, astronomer Maria Mitchell gained worldwide fame when she became the first person to discover a comet with a telescope. A year later, she became the first woman elected to the American Academy of Arts and Sciences.

Volume 2: Reconstruction through World War II

Section 1: The Rise of Industrialism, Reconstruction, and the Gilded Age (1866–1900)

In many ways, the four decades after the Civil War expanded upon the technological innovations of the antebellum period. Railroads continued to expand upon the transportation revolution, culminating in the completion of the Transcontinental Railroad. The 1862 Pacific Railroad Act allowed the Union Pacific and Central Pacific Railroad companies to build two rail lines, one stretching east from Sacramento, California, and the other west from Omaha, Nebraska. The companies' rail lines met in Promontory, Utah, in May 1869 and ushered in decades of western migration.

Inventors like Thomas Edison and Alexander Graham Bell changed the American landscape even further. Edison pioneered the domestic and commercial use of electrical light and power in the 1870s and 1880s. His support of direct current (DC) distribution set off the “War of the Currents” when George Westinghouse and Nikola Tesla both championed alternating current (AC).

The Gilded Age was also the age of applied science or science applied to technology for economic gain. Thomas Edison personified this branch of American science, founding a multitude of companies based on his inventions, which made him one of America's richest inventors.

While early 20th-century science and technological innovations were numerous, perhaps the most important event of the age happened at Kitty Hawk, North Carolina, in 1903. Orville and Wilbur Wright, brothers and partners in a bicycle shop, accomplished the first heavier-than-air, controlled, power-driven human flight. Few people besides their sister, Katherine, who operated the shop when they were away experimenting, understood the importance of the Wright brothers' achievement. They would usher in a century wherein flight became central to the human experience.

Section 2: The Progressive Era and the Roaring Twenties (1900–1929)

While women had always played a role in American science and technology, the 20th century saw immense

improvement in women's education and increased opportunities for meaningful work outside the home. Alice Bryant invented a variety of surgical instruments; Lizzie Dickelman innovated agricultural mechanisms, including a chicken brooder and a grain bin; and Mary Phelps Jacob, also known as Caresse Crosby, invented the modern brassiere. Born in Germany, Amalie Emmy Noether moved to the United States when Jewish professors were fired en masse in her native land. In her new country, she made so many contributions to abstract algebra and theoretical physics that Albert Einstein called her the most important woman in the history of mathematics. Meanwhile, astronomer Annie Jump Cannon invented modern star classification.

Section 3: The Great Depression and World War II (1930–1945)

The worldwide depression of the 1930s, known as the Great Depression, hit the United States particularly hard. By 1932, one-quarter of all working Americans, 12 million people, were unemployed. The economic hardships created an antiscience climate and a weakening of the federal government's support of science. Research funding dried up, as did university programs, because newly minted doctors of philosophy had little or no chance of finding jobs. Moreover, many people pointed out that science had failed to predict the economic disaster and that applied technologies might have contributed to the depression. The environmental disaster that was the Dust Bowl could be laid, in part, at the foot of the tractors and plows that had allowed the overfarming of the Midwest.

The American entry into World War II in late 1941 effectively ended (though perhaps only temporarily) the nation's antiscience-and-technology phase. In many ways, the World War became a contest between two technological systems: the European system of making small numbers of highly engineered products versus the American system of making large amounts of replaceable goods. The United States effectively outmanufactured its enemies, building vast numbers of tanks, airplanes, ships, and other military goods that would win the wars in Europe and the Pacific.

The United States also benefited from the Nazi “brain drain,” when German-born scientists fled their

country for America. Most notable among these scientists were Einstein and Noether, but Enrico Fermi and Niels Bohr also came to the United States. During the war, Niels Bohr, along with Robert Oppenheimer and many others, worked at the Manhattan Project to develop the first nuclear bomb.

Volume 3: The Cold War to the Present

Section 1: The Cold War (1946–1979)

The scientific and technological success of World War II convinced the American people of the efficacy of state-funded science and technology research. Much of this research was aimed at Cold War military technologies, though the three decades after World War II also saw great strides in medicine, meteorology, ecology, and computer science.

Rachel Carson published her groundbreaking book *Silent Spring* in 1962, which described the adverse effect of chemical pesticides on the environment. The chemical industry rushed to discredit Carson as a hysterical and ill-informed woman. Today she is considered one of the founders of the American environmental movement.

In 1969, the National Aeronautics and Space Administration (NASA) launched Apollo 11, which became the first space mission to land a person on the moon. The nation rejoiced both in the accomplishment of the endeavor and in the fact that the United States had won the Space Race with Russia. To date, the United States is the only country to have landed human beings on the lunar surface. Though all the Apollo astronauts were men, a group of female pilots took and passed all the astronaut tests. Later dubbed the Mercury 13, these women were never an official part of NASA's astronaut-training program.

In 1972, Atari released the first video game, *Pong*, unleashing a video game industry that would come to dominate the home entertainment markets in years to come.

Section 2: The Post–Cold War Era (1980–1999)

The 1980s saw a revolution in computer technology spurred on by improvements in chip technology. Previous events, such as Jack Kilby and Robert Noyce

developing the first integrated chip and the launch of the IBM 360 in 1964, revolutionized computing by differentiating between architecture and computing materials. Smaller, more affordable home computers followed in the next decades, including the HP 9100A (1968), the first desktop computer; the MITS Altair 8800 (1975), the first hobby computer; and the Apple I (1976), Apple's first single-board computer. These advances soon created a world where computers became as commonplace as televisions and microwave ovens.

The 1980s also saw NASA's Space Shuttle program expand our knowledge of astronomy, space physics, and many other sciences. Sally Ride became the first American woman in space in 1983.

Section 3: The New Millennium (2000–Present)

While electronic innovations, from the iPod to the e-book and e-readers, characterize the last 20 years of American innovation, many Americans profess to be antiscience and against funding for public science. For example, NASA's Space Shuttle program ceased in 2011, ending a decades-long American space program. The shuttles had helped build the International Space Station, carried the Hubble Telescope to low-earth orbit, and serviced space stations, space laboratories, and satellites.

In 2017, more than 600 American cities hosted a March for Science to protest the politicization of scientific research and evidence-based public policies. At the same time, public scientists like astrophysicist Neil deGrasse Tyson and Bill Nye have attained rock star–like status in popular culture.

While a vocal minority of Americans are hostile to science, the vast majority of Americans embrace the contributions that science has made to their lives. Innovations in health care like the birth control patch; increasingly sustainable automobiles, including hybrid vehicles; and Internet shopping supported by PayPal are considered normal parts of American life.

The Human Genome Project, launched in 1990, was completed in 2000. The project identified all the genes in the human genome (not just the genes of one human) and was funded by the National Institutes of Health (NIH).

The early decades of the 21st century may prove particularly fertile ground for female scientists and inventors as schools and colleges work to encourage young women in science, technology, engineering, and mathematics (STEM) education. Women like

astronaut Mae Jemison, astronomer Jill Tarter, and animal scientist Temple Grandin have provided girls and young women with role models unavailable to earlier generations.

Chronology

- 1638:** Elizabeth Glover establishes colonial America's first printing press.
- 1641:** The first North American patent is issued to Samuel Winslow for salt processing.
- 1717:** Eleven-year-old Benjamin Franklin invents swim fins, beginning a long and varied career as an inventor and innovator.
- 1719:** Gunsmiths Robert Baker and Martin Meylin produce early Kentucky long rifles.
- 1721:** Cotton Mather promotes smallpox inoculations in Boston. During the American Revolution, the Continental Army's willingness to inoculate soldiers creates an advantage for the army against the British.
- 1742:** Benjamin Franklin's circulating stove, known as the Franklin stove, improves home heating.
- 1743:** The American Philosophical Society is founded in Philadelphia; the Society is still in operation today.
- 1749:** The lightning rod is invented by Benjamin Franklin to protect people and buildings.
- 1753–1758:** Jane Colden categorizes over 300 types of plants in the Hudson River Valley, making her America's first great yet largely unrecognized botanist.
- 1776:** Thomas Jefferson introduces the first swivel or revolving chair, eventually changing the way bored office workers use their time.
- 1782:** Rectangular, flat-bottomed boats, or flatboats, are introduced to navigate inland waterways for the purpose of affordably moving agricultural goods to market.
- 1787:** Oliver Evans invents the automatic flour mill, the first fully automated production system, which in turn makes flour more affordable.
- 1793:** Catharine Littlefield Greene and Eli Whitney invent the cotton gin, ushering in the age of King Cotton that would lead to the Civil War. Greene would be largely forgotten to American history until the 21st century.
- 1795:** Thomas Jefferson invents the wheel cipher for sending coded messages; variations on the wheel are used as late as World War II.
- 1801:** The first suspension bridge is built in Uniontown, Pennsylvania.
- 1801:** Philadelphia installs the nation's first fire hydrant. Before the widespread use of urban water systems and fire hydrants, large portions of cities regularly burned down.
- 1804:** The Burr truss is introduced in covered bridge technology.
- 1804–1806:** The Lewis and Clark Expedition, guided in part by Sacagawea, explores the American West. The expedition fails to find the Northwest Passage, a legendary waterway linking the Pacific and Atlantic oceans, but it does succeed as an ethnographical and biological survey team.
- 1805:** Oliver Evans invents a steam-powered amphibious vehicle, an early attempt at a submarine.
- 1806:** The coffee percolator revolutionizes coffee brewing; Americans gradually switch from tea to coffee consumption.
- 1807:** Robert Fulton builds the first American steamboat, and the Age of Steam begins.
- 1808:** The lobster trap allows for the capture of multiple lobsters in one trap.
- 1812:** A smoothbore, large-caliber Columbiad Cannon improves American seacoast defense.

- Columbiads prove so effective, they are used extensively during the Civil War.
- 1813:** Tabitha Babbitt invents the circular saw for sawmill use.
- 1817:** Construction begins on the Erie Canal. Often described as “the Eighth Wonder of the World,” the canal’s great scale inspired decades of American canal building, culminating in the massive Panama Canal.
- 1821:** The Lowell mill system is pioneered, turning thousands of young women into America’s early factory workers.
- 1827:** The Baltimore and Ohio Railroad becomes the first American railroad company. American railways will push westward expansion, industrialization, urbanization, and immigration.
- 1833:** The lockstitch sewing machine, forerunner to all modern sewing machines, is invented.
- 1834:** The combine harvester is introduced by Hiram Moore. It combines the functions of reaping, threshing, and winnowing grain crops in one machine.
- 1834 and 1836:** Female mill workers at Lowell, Massachusetts, organize the nation’s first significant worker’s strike against conditions created by the Industrial Revolution.
- 1836:** Samuel Morse develops Morse code for telegraph communication, making almost instantaneous communication possible.
- 1839:** George Pullman’s railroad sleeping cars revolutionize transcontinental travel; Charles Goodyear patents vulcanized rubber.
- 1847:** Maria Mitchell becomes the first American astronomer who uses a telescope to discover a comet. Mitchell becomes the first American female astronomy professor.
- 1848:** The pin tumbler lock is invented by Linus Yale Sr.
- 1849:** Abraham Lincoln patents a floating dry dock.
- 1851:** Elias Howe patents the zipper, changing clothing design forever.
- 1853:** The spring clothespin is patented.
- 1856:** The hand-cranked eggbeater is introduced to American cookery. Food made with whipped eggs, or meringue, explodes in popularity.
- 1857:** Mass-produced, rolled toilet paper is developed by Joseph Gayetty.
- 1858:** The pencil eraser, screw-top pepper shaker, twine knotter, dustpan, and mason jar are patented.
- 1859:** The first moving staircase, known as the escalator, is invented.
- 1860:** Ellen Demorest markets the first paper sewing patterns. Combined with home sewing machines, the patterns inspire an explosion of home-based sewing.
- 1861:** The Kinetoscope, postcard, and hand-cranked machine gun are patented.
- 1861–1865:** Thousands of American women volunteer as nurses during the Civil War and professionalize nursing.
- 1863:** The National Academy of Sciences is founded.
- 1864:** Rebecca Crumpler graduates from medical school, becoming the nation’s first black female physician. She pioneers health care for women and children.
- 1865:** John Stetson invents the cowboy hat during a hunting trip.
- 1866:** The wall-mounted urinal is introduced to public bathrooms.
- 1867:** The steam-powered motorcycle, or Roper Steam Velocipede, is invented, along with paper clips, barbed wire, ticker tape, water-tube boilers, and the railroad refrigerator car.
- 1869:** The steam-powered vibrator is invented. The Transcontinental Railroad is completed with the driving of the “Last Spike” in the Utah Territory.
- 1870:** Famed beekeeper Moses Quinby invents the first bee smoker. The can opener, feather duster, and sandblaster are also invented.
- 1873:** Earmuffs are invented by Chester Greenwood to solve his cold ear problem. No one knows why he didn’t just put on a hat.
- 1874:** The spork, ice cream soda, jockstrap, and QWERTY keyboard design are invented.
- 1877:** Thomas Edison invents the phonograph at his Menlo Park, New Jersey, facility.
- 1879:** James Ritty invents the “Incorruptible Cashier,” or cash register.

- 1880:** Amanda Jones invents the oil burner for home heating.
- 1881:** The electric chair is invented. The first execution takes place nine years later. The electric iron and metal detector are also invented.
- 1883:** The Brooklyn Bridge is completed with Emily Roebling as architect, a job she took over from the original architect, Washington Roebling.
- 1884:** The first “skyscraper” is built in Chicago.
- 1885:** George Eastman introduces rolled photographic film.
- 1888:** The AC induction electric motor is patented, as are the ballpoint pen and Salisbury steak.
- 1886:** Josephine Cochran invents the first working mechanical dishwasher. In spite of this invention, people continue to leave their dishes in the sink.
- 1887:** The National Institutes of Health (NIH) is founded.
- 1890:** The tabulating machine, shredded wheat, smoke detector, and stop sign all receive patents.
- 1891:** George Ferris builds the first Ferris wheel for Chicago World’s Fair. The wheel is meant to be the centerpiece of the fair and more impressive than the Eiffel Tower, which had been the great innovation of the previous World’s Fair in Paris.
- 1892:** Sarah Boone patents the ironing board, and Frank Hall invents the Braille typewriter.
- 1895:** The Tesla-Westinghouse Niagara Falls Power Plant begins national electrification.
- 1897:** The Yerkes Observatory opens and becomes the birthplace of modern astrophysics.
- 1899:** The National Consumers League is founded.
- 1900:** Firestone introduces the first rubber, pneumatic automobile tire.
- 1901:** The key punch and mercury vapor lamp are invented. Ransom Olds uses the first assembly line to build the first mass-produced automobile, the Oldsmobile Curved Dash. Disposable safety razors are introduced to Americans.
- 1902:** The hearing aid and air conditioner are patented.
- 1903:** Orville and Wilbur Wright pilot the *Wright Flyer I* in the first powered, sustained mechanical flight. The United States acquires the Panama Canal. Mary Anderson patents the windshield wiper.
- 1904:** New York City opens the first subway system.
- 1906:** Herpetologist Mary C. Dickerson publishes *The Frog Book*. She will describe 20 new reptile species in her lifetime.
- 1907:** Mary Pennington becomes first head of the Department of Agriculture’s Food Research Laboratory. The telescoping curtain rod and paper towel are invented.
- 1908:** The first Model T is produced by Ford Motor Company.
- 1912:** The first electric traffic light is installed in Salt Lake City.
- 1914:** Alice G. Bryant is accepted into the American College of Surgeons. She will invent dozens of surgical tools. Caresse Crosby patents the first modern brassiere.
- 1919:** The pop-up toaster is invented to prevent burned toast.
- 1925:** Richard Drew of 3M invents masking tape.
- 1929:** Freon and the tampon are invented.
- 1931:** The Empire State Building opens its doors.
- 1933:** Albert Einstein immigrates to the United States, fleeing Nazi Germany. Famed mathematician Amalie “Emmy” Noether also leaves Germany and takes a position at Bryn Mawr College. Wide-band frequency modulation (FM) is patented. The Tennessee Valley Authority (TVA) is chartered by the U.S. Congress.
- 1934:** George Beauchamp files the patent for an electric guitar (hollow body).
- 1935:** The parking meter and surfboard fin are invented.
- 1936:** Part of a New Deal jobs program, the Hoover Dam is completed.
- 1937:** George Stibitz builds the first digital computer.
- 1939:** The first automated teller machine (ATM) is invented.
- 1941:** Hedy Lamarr patents spread-spectrum technology. Les Paul introduces the first solid-body electric guitar.
- 1941–1945:** American shipyards build 2,710 Liberty ships. The U.S. Department of Agriculture

- develops a system for mass production of penicillin.
- 1942:** The 1700-mile Alaska Highway is completed.
- 1945:** Percy Spencer invents the microwave oven.
- 1945:** The atomic bomb is perfected at Los Alamos, New Mexico. The United States drops two atomic bombs on Hiroshima and Nagasaki in Japan, ending World War II.
- 1946:** Tupperware is introduced to consumers; Brownie Wise revolutionizes marketing with the Tupperware party.
- 1947:** The U.S. Air Force demonstrates the first supersonic aircraft flight.
- 1948:** The first video game, *Tennis for Two*, is developed.
- 1949:** Grace Hopper writes the first compiler program. The crash test dummy and aerosol paint are invented.
- 1951:** Bette Nesmith Graham invents correction fluid, first called “Mistake Out.”
- 1952:** John Hetrick invents the first automobile air-bag. The plastic bread clip is invented by Floyd Paxton. The bar code is patented.
- 1954:** The Ziploc bag and TV dinners are introduced to American consumers. The first portable transistor radio, the Regency TR-1, is introduced, changing American musical culture.
- 1955:** The USS *Nautilus*, the first nuclear submarine, is launched. Jonas Salk invents the polio vaccine.
- 1957:** Gordon Gould theorizes the laser; three years later, Theodore Maiman builds the first laser.
- 1958:** Jack Kilby builds the first integrated electronic circuit. The National Aeronautics and Space Administration (NASA) is founded.
- 1959:** The first weather satellite, Vanguard 2, is launched. The Satellite for Global Navigation Satellite System is also launched.
- 1960:** The birth control pill is approved by the Food and Drug Administration.
- 1962:** Rachel Carson publishes *Silent Spring*, warning Americans about the dangers of chemical pesticides.
- 1963:** Mollie Orshansky develops the government measurement for poverty while working at the Social Security Administration. The first computer mouse is invented—it is made with wood and has two wheels.
- 1964:** The flat-panel plasma display, now common in televisions, is invented, as is the eight-track cartridge system for playing sound.
- 1965:** Artificial turf is installed in the Houston Astrodome. Ted Nelson develops hypertext, and George Sweigert patents the first cordless telephone. The compact disc, or CD, is developed.
- 1969:** The Apollo 11 lunar module lands on the moon and returns safely to earth. The Boeing 747, the first wide-body jet, has its first test flight.
- 1970:** The University of Hawaii invents the first wireless local area network.
- 1971:** John Blankenbaker invents the first personal computer. The microprocessor computer chip is produced at Intel. The first electronic mail, or e-mail, is sent by Ray Tomlinson. The first artificial heart is successfully implanted in a human.
- 1972:** Magnavox releases the first home use video game console. The Global Positioning System (GPS) is invented, though it was patented one year later.
- 1973:** Voice mail, the catalytic converter, and personal recreational watercraft are invented. Martin Cooper invents the first handheld mobile phone. Skylab, the United States’ only space station, is launched.
- 1975:** The digital camera is invented.
- 1978:** The sofa bed and microwave popcorn are invented.
- 1981:** The space shuttle is developed by NASA.
- 1982:** IBM introduces a low-cost home computer.
- 1983:** The Internet (not the World Wide Web) is first implemented by the National Science Foundation (NSF). Sally Ride becomes the first American woman in space.
- 1984:** Search for Extraterrestrial Intelligence (SETI) is founded. Chuck Hull patents the first 3-D printer. CD-ROM, DVDs, and flash memory change the data storage and music industries.

- 1985:** Microsoft introduces the Windows program.
- 1988:** Tilt-and-roll wheeled luggage is invented by pilot Robert Plath.
- 1991:** Linux and hypertext are introduced to the public, thereby simplifying coding. National Public Radio hosts the first *Science Friday*, a program devoted to science.
- 1992:** The spinning hubcap is invented.
- 1994:** BellSouth develops the first smartphone.
- 1995:** JavaScript is invented.
- 1996:** The Universal Serial Bus is introduced, as is the MP3 audio format.
- 1997:** The *Mars Pathfinder* lands on Mars.
- 1998:** The first commercially available e-reader is sold; Google appears on the World Wide Web.
- 2002:** The birth control patch is made available to consumers.
- 2003:** Toyota introduces the hybrid electric/gasoline car.
- 2005:** YouTube goes online.
- 2008:** California hosts the first Maker Faire.
- 2013:** The first autonomous, or self-driving, car moves through public traffic.
- 2017:** The Cassini-Huygens mission to Saturn comes to an end after 19 years of exploration and a myriad of astounding findings.

1. Colonial America and Enlightenment Science

OVERVIEW

Between America's colonial period and 1860, profound changes occurred in the ways people thought about the world around them. During the colonial period, Enlightenment ideas began to break through the ancient, collective veil of folklore and superstition that Western culture had used to explain the workings of the natural world. This revolution in scientific thought processes did not happen overnight, but it did develop quickly in historical terms. In the hands of individuals with the necessary time, intellect, and scientific aptitude, these groundbreaking changes in perspective promoted inquiry, experimentation, and invention that created remarkable consequences for the future of science and technology. Following the American Revolution, founders focused the use of science and technology on projects that supported the needs of the new nation. This attention to the value of technology and the promotion of invention and innovation improved America's infrastructure, allowing Americans to begin construction of a strong, viable economic system based upon several key components. The advancements of the 19th century focused on three primary areas: transportation, the harnessing of electricity, and the improvement of industrial processes. These innovations would have a major impact on America's national position in the world, its economic prosperity, and on the path of American history.

Enlightenment Science in the New World

These advances would not have been possible without the impact of the Enlightenment, a philosophical movement that completely changed the way in which people

perceived the world around them. For most people living in early colonial America, nature was an ominous, unseen force not governed by reason or measurable, calculable factors; it was, as historian David D. Hall has described it: a "world of wonders." Signs and portents appeared in the sky and with the illness, malformation, or death of animals or humans, or in unnatural occurrences such as talking animals or human infants. This ancient belief system was as real and valuable to colonial people then as the understanding of the scientific method is to us today, and the difference between the two philosophies presents a crystal-clear illustration of the effects of scientific changes that emerged during the early period of America's history.

The Enlightenment promoted the use of deductive reasoning to understand how the world worked, as opposed to the earlier system of inductive reasoning. For those familiar with the tenets of this new "Age of Reason," simply observing an event—an epidemic, for instance, or a crop failure—could not be explained in terms of society's bad behavior or the vindictiveness of an enemy. Enlightenment thinkers relied upon the gathering of data and its careful analysis, not supernatural forces. This approach had widespread implications for the future of American society, as Enlightenment thought encompassed politics, the structure of society, the idea of natural rights, religion, human relationships, economics, and many other areas, not just the scientific workings of the natural world. These different areas all worked together to create a nation that emerged as a promoter of challenging new innovation. The profound scientific and technological developments that occurred between 1607 and 1860 would not have been possible without this new way of thinking.

American Science and Indigenous People's Experience

The earliest colonists brought with them ideologies and systems that had been used in England and Western Europe for hundreds—in some cases thousands—of years. But the American environment was not the same as that of Europe. Therefore, adaptability was a necessary trait for the people who began to colonize America in the 17th century. While historical accounts relate colonists' amazement at the wealth of natural resources available, the new land was untamed and much of the flora and fauna plentiful beyond their wildest dreams, yet unfamiliar. Put simply, the new inhabitants of North America had to learn how to live there—and quickly, if they wanted to survive. Native Americans often eased the transition for those with access to and good relationships with them, both by teaching and often by actually helping to provision colonial settlements. While colonists named many of their settlements for the familiar places they had left behind, their new home required adjustment. For the earliest period, most settlers had little time for innovation beyond what was necessary to make their lives safe in their new country.

The Economic Realities

Economic gain represented the preeminent goal of the colonization process. The struggle for empire that dominated the 16th through 18th centuries focused on the conquest of land and the acquisition of wealth to build and maintain military power. The colonization of America was part of this struggle for empire, and it was not driven by individuals but by monarchies and commercial interests. While individual colonists came to America for their own personal reasons, such as religious freedom or a desire for adequate land upon which to make a better life, the “planting” of colonial settlements was funded primarily by various investors—proprietors or joint stock companies, for instance—or by royal charters. These entities intended to profit from their investments, and to do that, colonies needed to discover viable, potentially lucrative goods or processes that could be sent back to enhance the investors' bottom line and, as a result, the economic power of

their nation. The more wealth a nation could acquire, either on its own or indirectly, the more powerful it became on the world stage.

The time necessary and degree to which each colony was able to accomplish this goal depended greatly upon the primary reason the colony was founded, where it was located, and who populated it. While profit-making was always a motivation for investors, colonies such as the one settled by Puritans at Massachusetts Bay did not feel the same pressure to produce as Virginia, for instance, although both were funded by joint stock companies. This pressure often abated slowly; the first successful settlement at Jamestown in 1607 (the initial failed settlement, the famous lost Roanoke colony, was attempted in 1585) got off to a very rocky start. After harvesting timber and unsuccessfully searching for gold, in 1612, the Jamestown colony finally found a viable crop—tobacco; this commodity would fuel the economy well into the latter part of the 18th century. Each colony had its own experiences with the determining factors of success in a predominantly agricultural society: geography, climate, natural resources, and labor. Discovering ways to make colonies profitable for investors required experimentation, innovation, and revision. Although basic and primitive, the first foray of colonists into establishing settlements, taming the land, and transforming natural resources into revenue-producing products represents the earliest example of the use of science and technology by western Europeans on American soil.

These early efforts transpired under the most difficult of frontier conditions, and the tools available to colonists were virtually the same as those used elsewhere for hundreds of years. But once established, the settlements and systems implemented by colonists provided the foundation that supported American growth and innovation. As marketable products and financial resources increased, so did trade, and with an increase in trade came a better standard of living. Housing that had once consisted of one-room, rough log structures now began to have more formal floor plans, brick walls, and glass windows. The ships that carried naval stores, tobacco, rice, and other products away from America returned from Europe with fabrics, pottery, paper, and luxury goods such as fine soaps and gloves. Ships from the Caribbean colonies

brought sugar, molasses, and slaves to the mainland colonies and returned to their own ports with barrel staves, vegetables, flour, and salted meat and fish.

This burgeoning trade came at a cost, however. Through a series of navigation acts, the mercantile system existing between England and her mainland colonies dictated that only raw materials could be exported from America and that finished, or manufactured, goods must be imported to the American colonies from the British Empire. While the home manufacture of some items was clearly necessary, these products were only for personal use; items such as knitted stockings and other similar finished articles of clothing, for example, were not to be manufactured on a large scale and exported to England or any other country. In short, mercantilism was the economic engine that ran the colonial system, and for the integrity of the system to be guarded, it had to remain in a closed loop. This prohibition of large-scale manufacturing of finished goods suppressed the need for much technological innovation during the colonial period.

The Challenges of a Colonial Endeavor

In the colonies' agriculture-based society, labor was scarce. Therefore, time and energy resources went to production, not innovation. Simply put, the farmer's (or blacksmith's, or printer's) priority was feeding his family, not designing new tools or systems. In addition, little capital was available to fund some of the more viable technology-based businesses such as foundries or mining operations, and there was little need. England's Iron Act (1750), for example, limited American colonial innovation in the foundry business by prohibiting plating operations, establishment of new forges for the production of tools, the building of new mills, and the production of hardware. The Iron Act restricted America's output of iron exports to raw material only. Furthermore, in accordance with the mercantile system, exports were allowed only to the British Empire. With such restricted products and a closed market, there was little incentive for busy workmen to innovate.

Science and technology did expand in areas not related to manufacturing, however. As the basis for a primarily agricultural society, the study of botany and agronomy proliferated as farmers and plantation owners

attempted to grow better crops and harvest and process them more efficiently in hopes of increasing their market value. As markets changed due to weather, disease, pests, or political crises, planters experimented with new crops to maintain their production and income. For example, the French and Indian War (1754–1763) resulted in an increase in the cost of shipping exports, which caused many South Carolina rice planters to add indigo as a secondary crop. Several years of experimentation by agronomists such as Eliza Lucas Pinckney revealed that indigo could be grown in conjunction with rice, yet it was easier to ship and more profitable. Further experimentation resulted in better strains and more efficient and effective processing methods, which only served to increase the profitability of the crop. In Virginia, tobacco was the cash crop that kept the colonial economy running, fueled by a growing reliance on slave labor. However, tobacco is notoriously hard on the soil. After many decades of extensive production in Virginia, farmers were forced to search for an alternative to tobacco to compensate for the dwindling land available to support its culture. Experimentation and improvement resulted in the discovery of wheat as the most viable secondary export crop. In the northern colonies, where large-scale plantations were not feasible due to climate or geography, naval stores (the production of lumber and timber for ships' masts, turpentine, and tar) provided a lucrative economic base. This supported and eventually expanded into shipbuilding as an important industry in the New England colonies and represents one instance where the production of raw materials for export existed alongside a permitted manufacturing system.

The Wonders of the "New World"

While the previous examples illustrate the role of science and technology in the growth of the American economy, evidence is even more visible in the study of the natural world of zoology, geography, geology, astronomy, physics, chemistry, and biology. The interest in and study of these disciplines created a vivid dividing line between reliance upon "wonders" and a better understanding of the universe based upon deductive reasoning and verifiable facts. This gained insight resulted not only in a new way of looking at the world; it also promoted innovation and invention.

One of the best-known examples of someone interested in such scientific thought is Benjamin Franklin. Almost every schoolchild knows the story of Franklin's electrical experiment with the kite and the key, an exercise that led to the invention of the lightning rod; this invention saved many a building from destruction by fire. Franklin's 1752 experiment and discovery that electricity operates in a "fluid" manner by flowing between positive and negative charges is generally considered the beginning of American scientific progress, and many of the terms related to electricity, such as "battery," "positive," "negative," "charge," and "conductor," were coined or used in a new way by Franklin. However, Franklin also unlocked a secret of the natural world that has become indispensable; his experiment became the basis for one of the most important components of America's future scientific and technological development—the harnessing of electricity. Franklin's practical, fertile mind and inquisitive nature led him to invent numerous helpful items including bifocal lenses, the flexible catheter, swim fins, and an improved stove. He also invented the less well-known but curious and beautiful musical instrument, the glass armonica, which produces a haunting sound due to the oscillation of sound waves produced by the touch of a finger on rotating glass bowls of various sizes. Franklin was so involved with natural philosophy (the 18th-century term for the study of nature) that in 1743, he founded the American Philosophical Society, an organization committed to scientific study and inquiry that has operated up to the present day.

Thomas Jefferson became a member of the American Philosophical Society in 1780, representing the arrival of another generation of eminent American scientists. Jefferson's interests ran from architecture and agronomy (it has been said that he counted every pea grown in his gardens to analyze and improve his farming practices—the man loved peas) to zoology. Besides agronomy, Jefferson had an intense curiosity about natural history; he collected zoological specimens, including dinosaur bones, and he owned the Natural Bridge, a geological formation located in what is now Rockbridge County, Virginia. Like Franklin, Jefferson was also an inventor, although most of his inventions, such as the portable writing desk, swivel chair, and

pantograph, a device that copied documents as the author wrote them, were improvements of existing articles. Jefferson's most original and widely useful invention was a new design for a moldboard plow, the "Mouldboard of Least Resistance," which earned him accolades from learned societies in England, Italy, and France. As president of the United States, Jefferson ordered the Lewis and Clark expedition into the Northwest and the lesser-known Dunbar and Freeman expedition, which explored the southern reaches of the newly acquired Louisiana Territory. These endeavors gathered geographic information, collected climate and weather data, documented new types of flora and fauna, and identified Native American settlements and cultural practices, providing valuable scientific information for the understanding of the new nation.

With the finalization of the U.S. Constitution in 1787, the Founding Fathers began the process of building an American economy that would support the needs of the new nation. To this end, the government enacted new laws designed to improve infrastructure, promote industry, and protect American export markets. In 1790, Congress established the U.S. Patent Board, which issued its first patent that same year. The board consisted of three members, and Thomas Jefferson's duties as secretary of state included the role of patent commissioner.

The Dawn of the Industrial Revolution

The beginning of the Industrial Revolution in America coincided with the birth of the new nation. Until that time, most industry consisted of home manufacturing and not industrial production. The way in which this home production of goods functioned changed over time. Early on, one person might produce an item from start to finish. Later, the "putting-out" process emerged. In this type of production, the item passed through many hands, each person creating one part of the item before it was passed along to an individual responsible for handling the next step in the manufacturing process. Work was therefore "put out" to as many craftsmen—or women—as necessary to produce the finished product for the investor. At the dawn of the Industrial Revolution, mechanization began to replace the "putting-out" system.

American independence also ended the mercantile system and afforded creative Americans the opportunity to expand commerce and strengthen the national economy. This required expansion of the new nation's infrastructure and improvement and growth in agriculture and industry, bringing production of many items out of the home and into the factory and marketplace. The era of the Early Republic through 1860 brought innovation in three major areas: transportation, the harnessing of electricity, and the growth of industry. These three areas operated in conjunction with one another to develop a robust economy and bolster the international status of the United States.

The earliest use of machines for manufacturing purposes began with the textile industry. Once dominated by factories in England, the end of the American Revolution and the aspirations of the new nation opened opportunity for the United States to engage more fully in textile production and export. The first American mill for spinning cotton thread was built in 1793 by British immigrant Samuel Slater, who had worked in the textile industry in England. Slater had been lured to America when he learned that the Pennsylvania Society for the Encouragement of Manufacture and Useful Arts offered cash prizes to inventors who improved textile machinery or processes. Soon, Slater built mills in New England and eventually founded the mill town of Slaterville in Rhode Island. Slater's wife, Hannah, invented two-ply thread and in 1793 was the first woman to receive a U.S. patent. Construction of F. C. Lowell's power loom textile mill near Boston, Massachusetts, began in 1814; by 1821, the mill and the factory town of Lowell, Massachusetts, were complete. The machinery that ran both the Slater and Lowell businesses was not invented in the United States but was based upon designs created in England. What is remarkable about the equipment is that it was all built without blueprints or design plans; both Slater and Lowell recreated their machines from memory based upon English examples they had seen.

Both factories created widespread changes in American culture. Slater virtually jump-started the Industrial Revolution in the United States, the effects of which reached out to encompass almost every sector of society. Lowell's factory system revolutionized the way goods were processed, rapidly replacing the

"putting-out" system. When Lowell's factory was completed, he staffed it with young women who were drawn to the factory's location near Boston from their homes in the country. Lowell provided housing and other amenities for the young ladies while allowing them to participate in waged work. The arrangement pushed the envelope of what were considered proper boundaries for a young woman at the time; it also started a trend of country-to-city movement for participation in wage work.

King Cotton

Eli Whitney and Catharine Littlefield Greene's 1793 invention of the first commercially viable cotton gin was one of the most important contributions to the rise of the American textile industry. Whitney's invention set off the boom in cotton agriculture that would continue to expand for many decades; his subsequent implementation of the use of interchangeable parts in the manufacturing process would influence the path of the Industrial Revolution in America. Plantation agriculture dominated the South, and with a new way to more rapidly and efficiently process the bolls, more cotton could be grown for the textile industry. Climate, availability of arable land, and excellent growing conditions in the South allowed for the plantation system to expand, while limited arable soil and less agreeable climate encouraged industry to proliferate in the Northeast. Cotton could now be grown, processed, and milled more efficiently. The labor shortage that had prevented large-scale manufacturing in the North had been solved via new milling and looming machinery and rural-to-city movement for waged work. Labor shortages in the South were now filled via the institution of slavery. Both of these trends had profound effects upon the rise of industry in general and the movement of people from country to city; they also promoted the growth of the Cotton South because the two systems—agricultural and industrial—depended upon each other. By the middle of the 19th century, this tension would erupt in warfare.

Until the 1850s, all textiles were sewn by hand, but in 1846, Elias Howe received the first American patent for a mechanized sewing machine. In 1851, Isaac Singer developed what would soon become the

first commercially viable sewing machine, a treadle-powered model that used Howe's patented two-thread lockstitch method. Singer successfully mass-produced his machine, even developing an installment credit plan to boost his sales, but he soon found himself in a patent battle with Howe. Singer lost the lawsuit and was forced to pay royalties to Howe on every sewing machine he manufactured and sold. Howe became a very wealthy man, and the Singer name has been associated with sewing—particularly home sewing—ever since. At the same time, the example of the sewing machine marks a critical time in the growth of the Industrial Revolution in America and the impact of mass production on the American home.

The Transportation Revolution

Once goods were manufactured, they had to be transported to consumers. Reliable profits from technological advancements in manufacturing depended upon the ability to sell products at a reasonable price. The early 19th century witnessed transportation advances that made sending goods to market easier and less expensive than ever before. Prior to the early 19th century, goods had to be transported over land and along natural waterways. This arrangement worked well but was slow and expensive, and it burdened both producers and consumers, especially those in out-of-the-way places. Early attempts at canal building had begun in the late 1700s with the construction of a portage canal on the lower Susquehanna River in Pennsylvania; the project was completed in 1797. George Washington, Thomas Jefferson, and James Madison were part of a 1785 canal-building project under the auspices of the Potomac Company, and many other investors experienced varying degrees of success with their small canal-building ventures.

It was not until the completion of the Erie Canal in 1825 that the era of canal building was truly realized. Funded by the state of New York and begun in 1817, this 363-mile long waterway far surpassed the longest existing canal, the 27-foot-long Middlesex Canal in Massachusetts. Completion of the Erie Canal created a shipping lane from the western interior on Lake Erie all the way to New York and the Atlantic, opening western commerce to Europe and beyond. It also

opened up the West to importation of more readily available goods from points east. At the same time, transportation costs dropped; in some cases, the difference between the previous overland route and the Erie Canal route amounted to as much as 95 percent. The construction of the canal itself may have been an engineering wonder for its day, but the entire project was dug without the use of heavy equipment. By 1850, the state of New York had added eight additional canals that flowed south from the Erie.

Between the years 1815 and 1860, almost 4,300 miles of canals were built in the United States at a cost of \$189 million, most of which was funded by state governments. Canals represented a great boon to local, regional, and national economies. Construction required engineers, and canal construction, maintenance, and operation also required labor, material, and support services. Once completed, canal boats had to be towed by horses or mules that walked along the sides of the canal; those animals required care and handlers. Monitoring, repairs, and maintenance were constant expenses that required manpower to manage and execute. Therefore, in addition to the economic benefits derived from the ability to ship goods long distances over water at a heretofore unprecedented speed, benefiting local farmers as well as big-city vendors, canals provided jobs and income for a wide variety of workers along the entire length of each waterway.

Canals were not the only transportation improvement in the early 19th century. One drawback of the canal system was that these waterways could not accommodate large boats—only those with shallow drafts that could be towed by animal power. The invention of the steam engine and its subsequent use in both the locomotive and the steamboat facilitated the movement of people and cargo over a network of railroad tracks, rivers, and canals. While the earliest steam-powered vessels had been designed in the previous century, it was not until 1807 that Robert Fulton created what would become the nation's first commercially viable steamboat. After numerous adjustments and improvements to his original design, Fulton's *Clermont* chugged along the Hudson River on its way from New York City to Albany and back. The steam-powered vessel revolutionized riverine transportation of people and goods and encouraged the proliferation

of steamboat-powered movement of cargo and passengers along both major thoroughfares such as the Mississippi River as well as numerous smaller rivers and canals.

The nation's first steam-powered locomotive was designed by Peter Cooper of New York for the Baltimore and Ohio Railroad. Baltimore, Maryland, had been an important harbor, but construction of the Erie Canal threatened to take business away from the city. Beginning in 1828, B&O Railroad executives ordered the construction of tracks, and by 1830, they hired Cooper to build a steam locomotive, as it had become clear that their earlier plans for a horse-drawn train would prove inadequate to the task. From the establishment of this first 13-mile-long railroad in 1830, the total number of track miles expanded to total 30,000 by 1860, crossing the Appalachian Mountains and extending to connect the Midwest with the rest of the country.

The 1830s also brought advances related to the harnessing of electricity. Franklin's 18th-century discovery of the "fluid" nature of electricity and his related experiments were only the beginning of exploration and invention that would make the use of electricity commonplace. As early as 1831, Joseph Henry experimented with electromagnetic induction, which paved the way for the creation of generators and electric motors. While Englishman James Faraday usually gets the credit for this discovery, his work coincided with Henry's. Unfortunately for Henry and his legacy, Faraday published his work and obtained the first patent. Henry was selected, however, as the first secretary of the Smithsonian Institution upon its founding in 1846.

In the early 1830s, following a trip to Europe that undoubtedly influenced his interest, Samuel F. B. Morse designed his first prototype for the telegraph, a device that transmits messages via electrical impulse over a wire using a system of dots and dashes. Morse received funding for his invention and collaborated on the creation of Morse code with a fellow inventor Alfred Vail. In 1844, funded by a \$30,000 congressional appropriation, Morse completed his first telegraph line. Morse's first message traveled the 38 miles between Washington, D.C., and Baltimore, Maryland. By 1860, the United States' telegraph system contained

approximately 50,000 miles of telegraph line, and in that same year, Congress enacted the Pacific Telegraph Act of 1860, which authorized appropriations and the acceptance of bids to complete a transcontinental telegraph line.

The Consequences of Change

Between the colonial period, through the Revolutionary Era and the Early Republic and into the Antebellum period, American science and technology experienced revolutionary growth. This growth began with the simple, pragmatic need to merely stay alive in a new world and developed into the conscious creation of a national infrastructure that would support the needs of a new nation and improve the lives of its citizens. It eventually expanded to the development of machinery, agricultural and industrial production systems, communications, and the use of new power sources such as steam and electricity to power those systems. Some early scientists studied agronomy or gazed at the stars, explored paleontology, or invented useful items. Some were at the very forefront of American economic and cultural growth, manufacturing and transporting goods, transmitting information, and making daily life easier. These advances would be reconsidered, revised, and built upon over time; they had implications for the establishment of the United States, for the advent of such turning points as the Civil War, and in some cases for its outcome.

The various aspects of science and technology in the growing United States fit together like pieces of a fantastic design, all of which are intricately interwoven within the fabric of history. Philosophy, politics, population trends, and cultural change all contributed to the evolution of technology in America. The transition from pre-Enlightenment beliefs in "wonders" and other folk doctrines to the widespread understanding of deductive reasoning and the relationship between cause and effect fueled inquiry; indeed, it affected the very way in which individuals thought of themselves and their abilities. The increasing stabilization of the American colonies and the onset of Revolution offered opportunity for the expansion of markets that could be enhanced by forward-thinking philosophes and inventors. Early on, the U.S. government, as well as the private sector, encouraged the

invention, manufacture, and exportation of goods to strengthen the new nation via legislation and competition. The Industrial Revolution made good use of the development of newly invented machinery and processes, and by the end of the Antebellum period, the level of technological advancement in America would have astounded the early colonists.

These changes came with consequences, some intended, some not, but all were interrelated with the course of American history. Early textile manufacturing set in motion the movement of workers from farm to factory, which began a redistribution of population that would lead to the exponential growth of cities in the decades to come. The single example of cotton culture and manufacturing vividly illustrates the profound effect that the evolution of technology in America could have not only on the nation's economy but a seminal effect upon politics and the very question of the perpetuation of the Union. The acceleration of technological innovation and the economic and scientific advances that accompanied it set the United States on a path that the founding generations set in motion but which they never could have envisioned.

Lee Smith

Further Reading

- Barck, Oscar Theodore, and Hugh Talmage Lefler. 1958. "Industrial Life in the Colonies." In *Colonial America*, edited by Oscar Theodore Barck and Hugh Talmage Lefler, 335–50. New York: Macmillan.
- Bonomi, Patricia U. 2003. *Under the Cope of Heaven: Religion, Society, and Politics in Colonial America*. Oxford: Oxford University Press.
- Browne, Charles A. 1964. "Thomas Jefferson and the Scientific Trends of His Time." *Chronica Botanica* 8 (Summer): 363–423.

American Philosophical Society

The American Philosophical Society (APS) was the United States' first learned society. It emerged from a society that Benjamin Franklin founded in 1743. Its goal, according to Franklin, was to improve what he

called "the common stock of knowledge." Its members included a who's who of Americans and Europeans such as George Washington, John Adams, Alexander Hamilton, Thomas Jefferson, the Marquis de Lafayette, Baron von Steuben, and General Tadeusz Kosciuszko.

The APS focused on what was termed "natural philosophy" in its early days, meaning both scientific and technological studies. Thus, the society aided the general economic independence of the colonies through aiding the development of transportation, agriculture, and manufacturing. Additionally, the society gained great international acclaim through its advances in astronomy, one example of which was David Rittenhouse's plotting of the transit of Venus.

The society fell on dark days during the period of the American Revolution. However, with the aid of the state of Pennsylvania and the work of Samuel Vaughan and Francis Hopkinson, it revived quickly. Pennsylvania gave the Society a charter allowing it to correspond with scholars and scholarly institutions at any time on what it defined as legitimate business in peace and war. Pennsylvania also gave the APS land on Independence Square, on which it built Philosophical Hall (1785–1789). In the revived APS, each elected member became a participant on one of the following committees: Geography, Mathematics, Natural Philosophy (physics) and Astronomy; Medicine and Anatomy; Natural History and Chemistry; Trade and Commerce; Mechanics and Architecture; or Husbandry and American Improvements.

Among its many illustrious members, perhaps, Thomas Jefferson was the most illustrious. He became a member of the APS in 1780 and one of its counselors in 1791. Jefferson was a very active member of the Society. His work there demonstrated his vast knowledge and curiosity. He studied the Hessian fly, a threat to the American farmer, and encouraged a collection of mammoth skeletons by William Clark. Of course, the Lewis and Clark Expedition was his most famous undertaking with the APS. Jefferson connected Lewis with APS members who advised him on the upcoming expedition. Indeed, their journals and many of their collected artifacts are stored in the APS. In 1797 Jefferson became vice president of the United States for

one four-year term and president of the APS for the next 18 years.

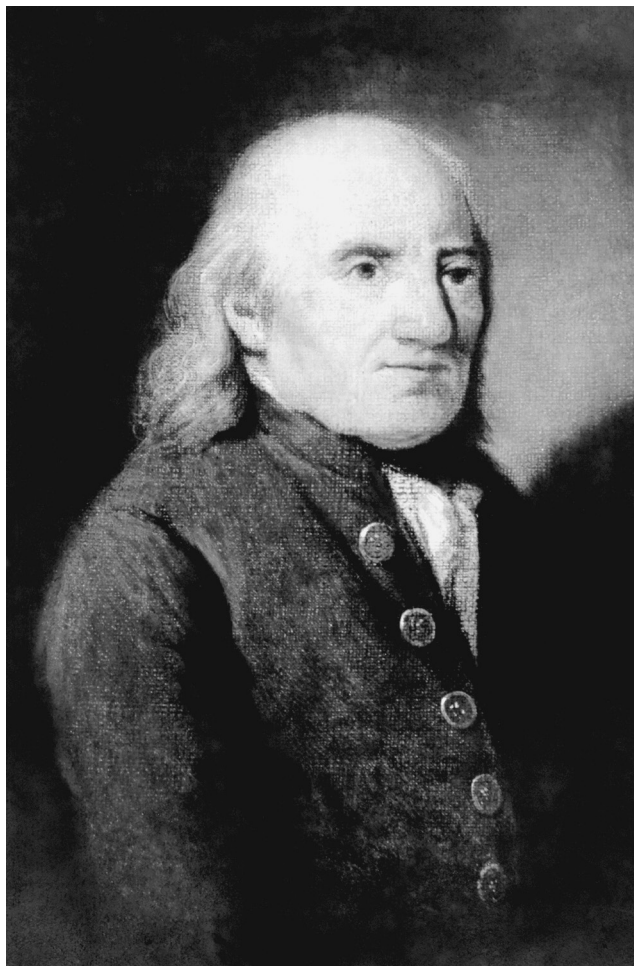
From the early independence period until about 1840, the APS remained a private concern. Nevertheless, it acted like a national institution—an academy of science, a national library, a museum, and a patent office. The APS provided valuable counsel to government officials. Additionally, the Society not only became the pattern for other learned societies but also spun off specialized organizations in many fields such as history, chemistry, and agriculture. It also gave space to other institutions, artists, cultural institutions, and sciences, including the University of Pennsylvania, Charles Willson Peale's museum, and Thomas Sully's studio, among many other cultural and even charitable organizations.

The APS's prominence is reflected in its membership over the years. It has included luminaries from many fields. In addition to a number of founding fathers and other 18th-century luminaries, its later members included John J. Audubon, Robert Fulton, Charles Darwin, Thomas Edison, Alexander von Humboldt, Louis Pasteur, Albert Einstein, Robert Frost, George C. Marshall, and Linus Pauling. Female members have included the Russian princess Yekaterina Dashkova, president of the Imperial Academy of Sciences in St. Petersburg, Russia; Elizabeth Cabot Cary Agassiz, Marie Curie, Gerty T. Cori, and Margaret Mead.

The APS has continued to grow, and its illustrious membership has aided in that growth. In the 1930s, for example, it began to develop in new directions, including offering a research grant program. A number of its small grants resulted in academic publications. Clinical medicine benefited from another program, and scientists were aided in conducting research into diseases. Currently, there are five separate grant programs that have grown from these earlier grants.

The APS's publications program has included a journal, a monograph series, memoirs, and a yearbook. Its library eventually required its own building. In 1981, Library Hall was erected, making it the third of the APS's buildings.

The Society acknowledges important accomplishments in a number of ways. It elects members who



John Bartram, a cofounder, with Benjamin Franklin, of the American Philosophical Society, posed for this portrait in or around the time of the Revolutionary War. His botanic garden, about three miles from the center of Philadelphia, Pennsylvania, is frequently cited as the first true botanic collection in North America. (Library of Congress)

have made superior achievements, and it presents medals and prizes. Among these prizes are those in navigation, astronomy or natural philosophy, contributions to American or European cultural history, neurobiology, and many others.

The APS library is the result of more than 270 years of collecting, including of material from the early days of the United States to the present. It holds more than 13 million manuscripts and books. It also collects scientific artifacts, including patent models. Of course, there are rare books in it, as well as photos, maps, and various paintings.

Particularly interesting and valuable holdings include William Penn's 1701 Charter of Privileges extending the right of people to enact their own laws. The chair that Thomas Jefferson used when writing the Declaration of Independence is also in the APS. There are also historic paintings on display, including one of Gilbert Stuart's famous portraits of George Washington.

Charles Willson Peale, the most famous and favorite artist of his time, housed his personal museum in the APS. Peale was noted for his promotional skills, which seem to have inspired the great P. T. Barnum himself. Indeed, he was not only a famous artist but also an inventor, naturalist, and educator. He once found a mastodon in upstate New York and sent it to the APS. He even charged people an extra half dollar to see it. For a time, people were obsessed with the "mammoth," and products like bread and cheese came in "mammoth" sizes. Cheese makers in Massachusetts even sent President John Adams a mammoth cheese.

Peale's museum collection became the basis for the APS's museum. From its founding in 1784, it was not only one of the first museums in the United States, it was one of its more popular and a lasting success. The collections covered many fields and included not only Peale's portraits of famous Americans but also stuffed birds and the mastodon.

The spirit of that museum continues to provide what it has called "rational amusement" to the populace. The APS museum has changing thematic exhibitions on history, art, and science, with a strong emphasis on the early history of the United States and, more particularly, Philadelphia. The museum exhibits

include rare manuscripts and books and examples of art and science, specimens of natural history, and other curiosities. The museum borrows works from other institutions as well.

For over 270 years, the APS has led the way in scholarly research and presentation. It has lived up to the hopes and goals of its founder, Benjamin Franklin, in bringing knowledge and understanding to the people. It continues to expand its reach and accessibility, promoting research and knowledge in numerous fields and to improve the "common stock of knowledge."

Frank Salamone

See also Franklin, Benjamin; Natural History; Peale, Charles Willson; Rittenhouse, David; *Vol. 1, Sec. 2*: Fulton, Robert; Jefferson, Thomas; Lewis and Clark Expedition; *Vol. 2, Sec. 1*: Edison, Thomas; *Vol. 2, Sec. 2*: Einstein, Albert

Further Reading

Archives of American Art. n.d. "American Philosophical Society Selected Records, 1784–1954." <https://www.aaa.si.edu/collections/american-philosophical-society-selected-records-10947>, accessed August 22, 2018.

Chinard, Gilbert. 1943. "Jefferson and the American Philosophical Society." *Proceedings of the American Philosophical Society* 87, no. 3: 263–76.

Duer, William Alexander. 1847. *The Life of William Alexander, Earl of Stirling, Major-General in the Army of the United States during the Revolution*. New York: Wiley & Putnam for the New Jersey Historical Society.

Primary Document: Memorial of the American Philosophical Society Favoring an Exploration of the Alaskan Coast (1868)

In response to financial difficulties and in an effort to keep its Alaskan Territory from the British, Russia sold Alaska to the United States in 1867 for just over \$7 million. Called "Seward's folly" at the time because then-secretary of state William Seward approved the purchase, the territory was put under the jurisdiction of the U.S. Army and known as the Department of Alaska. The area was, at the time of its acquisition,

largely unexplored by both the Russians and the Americans. On February 26, 1868, the American Philosophical Society reached out to the U.S. Congress with the aim of exploring the new territory in the "Interests of both Science and Commerce."

To the Honorable Senate and House of Representatives of the Congress of the United States

The Memorial of the American Philosophical Society Respectful Represents:

That the subject of the acquisition of the Alaskan Territory has been brought before this Society in its relations to science and the discussion resulted in the unanimous adoption of the following Preamble and Resolution:

“Whereas there is reason to believe that the North Western Territory recently ceded to the United States by the Russian Government possesses Resources in productions and naval facilities of much greater value and importance that has heretofore been supposed, the early development of which by exploration in Geology and Natural History is deemed to be of high importance to the Interests of both Science and of Commerce. Therefore—

Resolved that the Officers of this Society be requested to sign and transmit to Congress a Memorial asking the earliest possible action for the

commencement and execution of proper examinations upon the coast and within the said Territory by Officers of the Coast Survey and others of competent Scientific ability and experience.”

In pursuance of the direction of the above Resolution we very respectfully present this expression of the views of the Society as their Memorial, for the consideration and action of Congress and pray that adequate means may be adopted to make the explorations of the Government productive in the interests of Science, as well as those of Commerce, and of the extension of the area of freedom and civilization.

Philadelphia, February 26th, 1868

Geo. B. Mood, President

Chas. B. Trega, Secretary

Source: Records of the U.S. Senate, 1789–2015. “National Archives and Records Administration.” <https://catalog.archives.gov/id/306402>, accessed August 22, 2018.

Astronomical Almanacs

An almanac is an annual publication running through a year, providing information on a wide range of topics such as weather forecasts, tidal phenomena, planting dates for farming, eclipses, moon phases, religious festivals, and national holidays. Although at first almanacs had an eminent astronomical use (thence the name), as time went by, especially in America, they acquired a much more utilitarian focus, including practical information such as deadlines for the payment of taxes.

The first American almanac was *An Almanac for New England for the Year 1639*. Published in Cambridge, Massachusetts, it was the work of William Pierce of Harvard College. The first recorded usage of the term “almanac” was by English philosopher Roger Bacon in 1267, but its etymology (that is, the origin of the word itself) is unknown. The almanac’s origins can be dated back to mid-16th-century England with the publication of the almanacs of John Dade, Anthony Askham, Thomas Buckminster, and Gabriel Frende. In England, by the 17th century the popularity of almanacs was such

that 400,000 copies were sold every year. After the Bible, they were the bestselling books. Richard Allestree’s almanac, which ran from 1617 to 1643, was a favorite.

The most relevant almanacs in the 18th century were: Nathaniel Ames’s *Astronomical Diary and Almanack* (Dedham, Massachusetts; 1725–1775); James Franklin’s (Benjamin Franklin’s brother) *Rhode-Island Almanack* (from 1728 onward); Benjamin Franklin’s own *Poor Richard’s Almanack* (1733–1758); and Benjamin Banneker’s (1792–1797). The longest-running almanac was Robert Bailey’s, first published in 1792 and later renamed *The Old Farmer’s Almanac*. There also existed comic almanacs such as *Poor Robin’s Almanack* or John Tully’s of Saybrook, Connecticut (the latter spanning from 1687 to 1702).

Although Franklin’s *Poor Richard’s Almanack* is often mentioned as the quintessential American almanac, it was far from being the longest running or the bestselling. Actually, Ames’s had a much larger number of readers—60,000—in contrast to the 10,000 circulation of *Poor Richard’s*. Ames’ *Almanack* featured zodiac signs, movable feasts, poems related to each month, anniversaries, and weather predictions.

To better understand the extent of the influence of almanacs in the colonial period, one has to take into account the other sources of information at the time—or rather, the lack of these. In the days before radio, television, and the Internet, obtaining reliable information was a difficult task. Newspapers were available, but those in rural areas (and most of the population did not live in urban centers) found it difficult to access them. Often, newspapers traveled slowly, and they were received in rural areas after weeks of delay, therefore rendering whatever information they might contain obsolete and out of date by the time they were read. Getting some news was relatively easy throughout the period, as it could be obtained from a multitude of sources—a traveler passing through town, a peddler, or acquaintances and neighbors. However, obtaining *reliable* news was altogether more complicated.

An almanac included a monthly calendar as well as tables of astronomical events. The astronomical knowledge contained in the first almanacs soon gave way to more scientific data in time. Seasonal changes were duly recorded; the daily weather was a topic of much interest. Nevertheless, weather predictions, despite the painstaking recording of weather phenomena, were mostly unreliable and inaccurate. Buyers of almanacs used the included blank pages as personal diaries, and those that have been preserved are invaluable sociological documents. One user of almanacs in this way was George Washington.

Typical information contained in almanacs included anniversaries, interest tables, exchange and postal rates, population tables, recipes, interesting trivia pieces, anecdotes, opinion essays, songs, ballads, proverbs, jokes, fictional works, statistical information, poems, home medical advice, and tips on housekeeping and farming. Other useful information was where courts were located and the days on which court was held, or information on government officials. With all the detail and wealth of information that they included, almanacs were a most useful compendium of all the information a citizen might need on a daily basis.

Almanacs constitute a window to popular culture and people's interests and concerns. For example, the

presence of astrological tables was due to the widespread folk belief in the influence of the planets on human behavior as well as on natural occurrences. The planets were also described, and tables on the movement of planets were featured. Gradually, American almanacs put a much greater emphasis on practical matters and less on astrology, in contrast to their British counterparts. This emphasis on practicality was due, to a great extent, to Puritan influence, as Puritans abhorred anything that did not have a practical purpose.

While many of the ideas contained in almanacs came largely from Europe, Benjamin Franklin, who espoused deist beliefs (the idea that observation and revelation is the key to the discovery of the existence of a supreme being or god), conveyed these newer ideas in his almanac. During the American Revolution, the publishers of some almanacs made clear their views and supported the revolutionary cause, as did Nathaniel Ames. *Ames' Almanack* explained to its readers how to make gunpowder. Later on, Benjamin Banneker, a renowned supporter of the abolitionist movement, chose to print in his almanac essays espousing that cause. Thus, almanac publishers could sway the public's stance on a given topic.

Almanacs continue to be popular in modern times. More often than not, they are now intended for a specific audience or address a specialized topic.

M. Carmen Gomez-Galisteo

See also Franklin, Benjamin; *Vol. 1, Sec. 3*: Mitchell, Maria

Further Reading

Drake, Milton. 1962. *Almanacs of the United States*. New York: Scarecrow.

Sagendorph, Robb. 1970. *America and Her Almanacs: Wit, Wisdom, and Weather, 1639–1970*. Dublin, NH: Yankee.

Stowell, Marion Barber. 1977. *Early American Almanacs: The Colonial Weekday Bible*. New York: Benjamin Franklin.

Tomlin, T. J. 2014. *A Divinity for All Persuasions: Almanacs and Early American Religious Life*. Oxford: Oxford University Press.

Primary Document: Aphorisms from *Poor Richard's Almanack* (1732–1758)

Benjamin Franklin wrote and published Poor Richard's Almanack from 1732 to 1758 under the pseudonym "Poor Richard" or "Richard Saunders." In addition to containing a wealth of information about weather and astronomical phenomena as well as agricultural notes, Franklin sprinkled his almanac with pithy aphorisms, many of them still relatively well known. The following is a selection of the best known of these aphorisms.

"There are no gains without pains."
 "One today is worth two tomorrows."
 "Have you something to do tomorrow? Do it today."
 "Industry pays debts while despair increases them."
 "Women and wine, game and deceit, make the wealth small and the wants great."
 "Keep thy shop and thy shop will keep thee."
 "The wise man draws more advantage from his enemies than the fool from his friends."

"Pride dines on Vanity, sups on Contempt."
 "A learned blockhead is a greater blockhead than an ignorant one."
 "The noblest question is the world is What good may I do in it."
 "The learned fool writes his nonsense in better languages than the unlearned, but still it is nonsense."
 "He that lives on hope will die fasting."
 "'Tis hard but glorious to be poor and honest."
 "Tricks and treachery are the practice of fools that have not wit enough to be honest."
 "Many have quarreled about religion and never practiced it."

Source: Franklin, Benjamin, and Benjamin Peirce. 1849–1851. *Poor Richard's Almanac for [1850–52]: As Written By Benjamin Franklin, for the Years [1733–41]: The Astronomical Calculations*. Annual illustrated ed. New York: John Doggett Jr.

Banneker, Benjamin (1731–1806)

Benjamin Banneker was a free African American, mathematician, astronomer, abolitionist, and an almanac author from Baltimore, Maryland. He published six almanacs between 1792 and 1797, as well as papers on a variety of subjects.

Banneker's mother and father were freed slaves. Banneker's grandmother taught him how to read. He became a very avid reader and would read the Bible to his family every evening. As a child, he lived on a farm with his family and attended a Quaker country school—his only exposure to formal education. He was an avid self-learner and would later teach himself literature and history. He also taught himself geometry along with any other mathematical subject he could find. He borrowed many textbooks to learn these subjects. Often he composed problems for himself to test his mathematical knowledge. When he was 22, he built a fully functional clock, based on a pocket watch that he had been given. It continued to keep

time until he died. He inherited his family's farm and made it into a success by growing and selling tobacco. He used his love of math and machinery to create an irrigation system that would properly water his crops.

His interest in astronomy blossomed when he was 58 due to his neighbor, George Ellicott, who was a fellow mathematician and amateur astronomer. He gave Banneker books on astronomy as well as a telescope. Banneker became immensely interested in the stars and other celestial bodies. He studied eclipses and provided ephemerides—tables noting the positions of celestial objects at certain times—for his almanac. His ephemerides aided sailors and farmers greatly. Now the seas were easily navigable, and the accuracy of sowing seeds at the right time of year was increased. Banneker was also Ellicott's field assistant in scientific endeavors. One included the land survey of the District of Columbia, which provided the first glimpse of the land where the future capital of the United States would be built. All of these scientific outings also helped him to write his almanacs.

Banneker's other contributions to the almanac dealt with the antislavery movement. He wrote to Thomas Jefferson, the secretary of state at the time, and criticized him for owning slaves. He compared it to the Americans being enslaved by the British. Banneker believed Jefferson to be an amiable man and open to conversation on African Americans being viewed as more than mere property. He included a full copy of his almanac with his letter. Jefferson's response to the letter was positive, and he passed the almanac on to the French Academy of Sciences to display. Jefferson hoped this display would act as significant proof of African American intelligence, and though Jefferson and Banneker continued to correspond frequently and some of the letters were published in Banneker's almanacs, Jefferson never voluntarily freed his own slaves.

The abolitionist community in Maryland also assisted in the publication of Banneker's almanacs. They believed this was a prime way to show the country the works of an African American. They also believed that it would help show that black intellectual abilities were on par with all other races. This is a topic that Banneker addresses in one of his most notable quotes: "The colour of the skin is in no way connected with strength of the mind or intellectual powers." In 1797 he published his final almanac. Even so, he still continued creating ephemerides. Banneker would, in his later years, publish writings on bees and the life cycle of locusts.

Banneker died in 1806 at the age of 74 in his log cabin. He had had a lifelong issue with alcoholism, which significantly worsened in his later years. The disease may have played a significant role in his death. Suspiciously, during Banneker's funeral, his cabin

was burned down. The cause of the fire was never discovered. His clock, many writings, and most of his possessions perished in the fire. His family was only able to recover a few of his books and belongings. Most of his remaining property found its way to museums and private buyers. Many of them would eventually donate Banneker's belongings to museum collections to preserve them.

After his death, many myths and legends arose about him, one of them being that he had actually helped build Washington, D.C., in addition to surveying its land. Another said that he built his clock after being inspired by a sundial. Banneker's work was highly influential and provided a stage for abolitionists to get their messages of equality out effectively. His work also provided aid to the everyday man for everyday endeavors. His almanacs remain some of the most influential scientific work to come out of the early United States.

Michael R. Fluhrer

See also Astronomical Almanacs; Three-Wheel Clock

Further Reading

- Cerami, Charles A., and Robert M. Silverstein. 2002. *Benjamin Banneker: Surveyor, Astronomer, Publisher, Patriot*. New York: John Wiley and Sons.
- Franklin, Benjamin, and Bob Blaisdell. 2013. *Poor Richard's Almanack and Other Writings*. New York: Dover.
- Rothenstein, Richard. 2017. *The Color of Law: A Forgotten History of How Our Government Segregated America*. New York: Liveright.
- Wadsworth, Ginger. 2003. *Benjamin Banneker: Pioneering Scientist*. Minneapolis: Carolrhoda Books.

Primary Document: Letter of Thomas Jefferson to Benjamin Banneker, Expressing Jefferson's Belief That Blacks Had Talents Equal to Other Races (1791)

African American inventor, author, naturalist, and surveyor Benjamin Banneker was hired by Thomas Jefferson to undertake a survey of western New York. The two men engaged in a correspondence upon a

variety of matters, including their ideas about racial equality or lack thereof. Jefferson's letters to Banneker reveal inconsistencies in the Virginia slave owner's beliefs about black Americans.

Philadelphia Aug. 30. 1791.

Sir,

I thank you sincerely for your letter of the 19th. instant and for the Almanac it contained. No body wishes more than I do to see such proofs as you exhibit, that nature has given to our black brethren, talents equal to those of the other colours of men, & that the appearance of a want of them is owing merely to the degraded condition of their existence both in Africa & America. I can add with truth that no body wishes more ardently to see a good system commenced for raising the condition both of their body & mind to what it ought to be, as fast as the imbecillity of their present existence, and other circumstance which cannot be neglected, will admit.

I have taken the liberty of sending your almanac to Monsieur de Condorcet, Secretary of the Academy of sciences at Paris, and member of the Philanthropic society because I considered it as a document to which your whole colour had a right for their justification against the doubts which have been entertained of them.

I am with great esteem,
Sir,

Your most obedt. humble servt.
Th. Jefferson

Source: Thomas Jefferson to Benjamin Banneker, August 30, 1791. Manuscript letter. Manuscript Division. Library of Congress.

Primary Document: Frontispiece of Benjamin Banneker's *Pennsylvania, Delaware, Maryland and Virginia Almanack and Ephemeris (1792)*

Benjamin Banneker's Pennsylvania, Delaware, Maryland and Virginia Almanack and Ephemeris was published from 1792 to 1797. Banneker's mathematical and astronomical prowess made his almanacs best sellers. Reproduced here is the text from the frontispiece of his 1792 Almanack.

Benjamin Banneker's Pennsylvania, Delaware, Maryland and Virginia Almanack

and
Ephemeris,
For the Year of Our Lord 1792;

Being the Bissextile, or Leap-Year, and the Sixteenth Year of AMERICAN INDEPENDENCE, which commenced July 4, 1776.

CONTAINING the Motions of the Sun and Moon, the True Places and Aspects of the Planets, the Rising and Setting of the Sun, Place and Age of the Moon, &c.—The Lunations, Conjunctions, Eclipses,

Judgment of the Weather, Festivals, and other remarkable Days; Days for holding the Supreme and Circuit Courts of the *United States*, as also the useful Courts in *Pennsylvania, Delaware, Maryland, and Virginia*. Also—several useful Tables, and valuable Receipts.—Various Selections from the Commonplace-Book of the *Kentucky Philosopher*, an *American Sage*; with interesting and entertaining Essays, in Prose and Verse—the whole comprising a greater, more pleasing, and useful Variety than any Work of the *Kind and Price in North America*

Source: Goddard, William, and Angell, James. *Benjamin Banneker's Pennsylvania, Delaware, Maryland and Virginia Almanack and Ephemeris, for the Year of Our Lord 1792*. Washington, D.C.: American Memory, Library of Congress.

Bifocals

Bifocals are eyeglasses with two distinct lenses, each to correct a different optic problem. Generally, they suit people who have a problem focusing on nearer objects—"presbyopia"—but who also require a correction for "myopia" (nearsightedness), "hyperopia" (farsightedness), and/or "astigmatism," an inability to focus on an object to get a clear view instead of a blurred one.

Although there is some dispute, most scholars who study the issue hold that Benjamin Franklin invented bifocals. In 1824, the inventor of the trifocals, John Isaac Hawkins, came up with the term "bifocals," attributing their invention to Benjamin Franklin, as did the editors of the *Gazette of the United States*, an early Federalist newspaper.

There is a story that Franklin grew tired of switching from one pair of glasses to another and so found a way to bind two different lenses into the same pair of glasses.



Benjamin Franklin invented bifocals in 1824. Here, he holds a paper with his drawing for the invention, his face reflected in a mirror so that the paper can be easily viewed. In 2018, estimates showed 75 percent of adults used some sort of vision correction. (Bettmann/Getty Images)

Originally, the distance lenses were placed on top and the reading lenses on the bottom. For some time, people followed the pattern set by Franklin of melding two lenses together. Eventually, improvements came about because of the fragility of bifocals. Near the end of the 18th century, Louis de Wecker invented a means for fusing the two sections together to strengthen the glasses. John L. Borsh later patented the process in 1908.

Currently, a majority of bifocals have a reading lens molded into a previously constructed primary lens. There are many different shapes and sizes for the reading lens. Additionally, progressive lenses are replacing bifocals, generally because they do away with troublesome lines and also serve people's vanity in not making it so obvious that they are wearing bifocals, which many still identify with old age.

Progressive lenses may also ease the problems that many people have with bifocals. Some people experience headaches or dizziness from wearing bifocals. Moreover, the small area allowing for reading in many bifocals can take some time and adjustment to use. The reader must move his or her head up and down or move the eyes to find the text. This can be great trouble given the straight-on view one needs to use for reading computer monitors. Trifocals or monofocals can help solve this problem.

The first patent priority date for progressive lenses went to Owen Aves in 1907. Aves's design differed from that of modern progressive lenses because it had a conical back surface coupled with a front portion that was cylindrical. It also had axes that opposed each other to allow a power progression. This model was never put on the market. There were other inventors after Aves, but it appears that Duke Elder developed the first progressive lenses marketed in 1922. These were made from aspherical surfaces. In 1955, Irving Rips at Younger Optics produced a blended lens: the Younger Seamless Bifocal.

In 1959, the first lenses of modern design, the Varilux & Carl Zeiss lenses, were developed by Bernard Maitenaz. Predictably, these early lenses were of rather crude design and much head tilting was still required. Soon, however, asymmetrical lenses were developed to aid comfort and vision. Computer technology has helped in perfecting progressive lenses, allowing for greater precision to aid each patient. Other advantages of progressive adjustment lenses

(PALs), are that they always offer some place in the glasses to give the correct focus for whatever one wants to see. They are typically easier for most people to adjust to because there is no line between lens areas. However, one must move one's head from side to side when reading. Cost is another problem with progressive lenses; they are double the cost of bifocals.

Another option is bifocal or progressive contact lenses. Although bifocal contact lenses were invented in 1938, the first practical models were not available until the late 1980s, and rapid development took place in the 1990s. Improvements have continued, and now

a number of models address different needs and requirements. Ease of use and comfort has also kept pace with the new designs.

Frank Salamone

See also Franklin, Benjamin

Further Reading

Bennion, Elisabeth. 1979. *Antique Medical Instruments*. Los Angeles: University of California Press.
 Letocha, Charles E. 1990. "The Invention and Early Manufacture of Bifocals." *Survey of Ophthalmology* 35, no. 3: 226–35.

Primary Document: Benjamin Franklin's Letter Describing His Invention of Bifocals (1725)

In May 1725, Benjamin Franklin wrote a letter to George Whatley describing his invention of bifocals, or what he called "double spectacles." He wrote that he particularly enjoyed being able to see the food he was eating and the facial expressions of the people with whom he dined. The letter, an excerpt of which is reproduced here, also contained a sketch of the bifocals.

I therefore had formerly two Pair of Spectacles, which I shifted occasionally, as in travelling I sometimes read, and often wanted to regard the Prospects. Finding this Change troublesome, and not always

sufficiently ready, I had the Glasses cut, and half of each kind associated in the same Circle, thus, the same convexity of glass, through which a man sees clearest and best at the distance proper for reading, is not the best for greater distances. By this means, as I wear my spectacles constantly, I have only to move my eyes up or down, as I want to see distinctly far or near, the proper glasses being always ready.

Source: Benjamin Franklin to George Whatley (ca. 1709–1791), May 23, 1785. Letterpress manuscript. Manuscript Division, Library of Congress.

Bushnell, David (1740–c. 1824)

In 1775, David Bushnell, a Yale University student, had an idea for a submersible craft as a way to fight British ships attacking the United States during the American Revolution. The *Turtle*, called that because of its appearance, was powered by screw propellers and stayed submerged by using water as ballast—two more Bushnell discoveries. Able to approach enemy ships undetected, the *Turtle* would attach a time bomb to the hull and flee to safety.

But stealth and lethality were just two of the challenges Bushnell faced in building the *Turtle*. For example, what kind of materials would be used in constructing the hull? Since this was the 18th century, wood secured by iron hoops was the obvious choice. But how would the operator see? And, just as important,

how would he breathe? Bushnell solved the light problem by adding six small windows to the hatch. He dealt with the air problem by attaching two snorkels that closed when the craft was submerged. Because the air inside the submarine was limited by its size, the vessel was designed to travel on the surface or with its hatch and windows above water.

Operating the *Turtle* required more physical strength and stamina than David Bushnell possessed, so Continental Army sergeant Ezra Lee was at the controls when the submarine slipped into New York Harbor in September 1776 to attack British vessels. Lee tried to drill holes in one man-of-war but failed because the ship was lined with copper to ward off parasites that could damage her wooden hulls. Lee had to break off the attack. It would turn out to be the *Turtle's* only combat mission; it was lost the following

month when British frigates sank the tender ship that was trying to transport it out of the area. While it was recovered, it was never used again. Today, anyone wanting to see what the *Turtle* looked like has to settle for the full-size model on display at the U.S. Navy Submarine Force Library and Museum in Groton, Connecticut.

As for David Bushnell, he fought the rest of the Revolutionary War from land. He attempted to sink British ships with floating explosive mines and met with partial success, although a few of the mines detonated prematurely, killing innocent bystanders. In 1778, General George Washington proposed the formation of a unit specializing in sabotage, and Bushnell was placed in command. However, the British took

him prisoner in 1779. He was released in 1781, and his unit joined the Continental Army laying siege to Yorktown. After the Revolution, he left the army and settled in Georgia, where he taught school and practiced medicine. He died in Warrenton, Georgia, in about 1824.

John A. Morello

See also *Turtle Submarine*; Vol. 1, Sec. 2: Amphibious Steam Vehicle

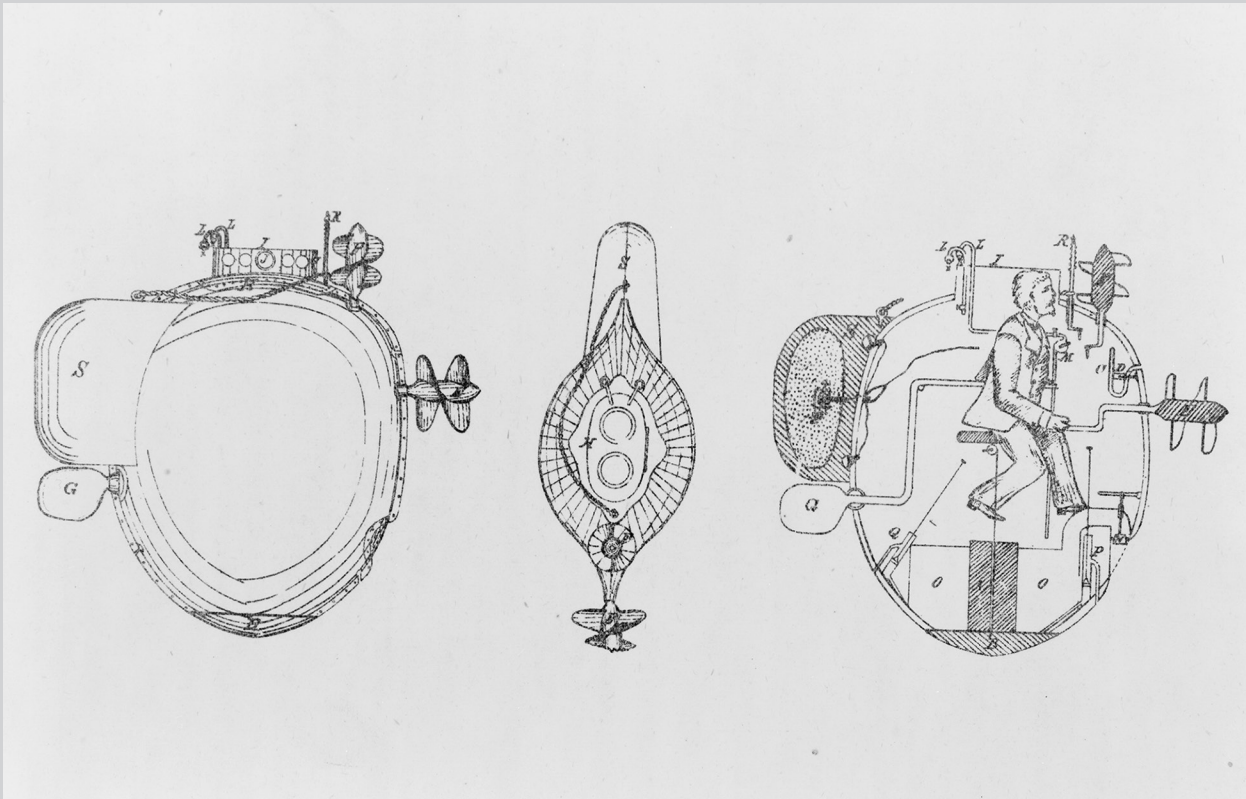
Further Reading

Swanson, June. 1991. *David Bushnell and His Turtle: The Story of America's First Submarine*. New York: Atheneum Press.

Primary Document: Engraving of David Bushnell's American *Turtle* (1775)

While a student at Yale in 1775, David Bushnell designed and built a one-man submarine that he called the *Turtle*. In 1776, the *Turtle* tried unsuccessfully to attach bombs to the underside of British warships in New York Harbor. This print from an 1881 publication shows three views of the *Turtle*.

Source: *The Beginning of Modern Submarine Warfare, under Captain-Lieutenant David Bushnell, Sappers and Miners, Army of the Revolution*. Being a Historical Compilation Arranged by Lieut.-Colonel Henry L. Abbot, Corps of Engineers, U.S.A. Willets Point, NY: Printed on the Battalion Press, Sergt. Carmichael and Pvt. Beck, Printers, 1881. Library of Congress.



Cast-Iron Pot. See “Saugus Pot”

Colden, Jane (1724–1766)

The first female botanist in America, Jane Colden learned science from her father's father, Cadwallader Colden, who had a hobbyist interest in botany and trained her in the Linnaean system of botanical classification. She studied flora in New York City, mainly along the Hudson River Valley. She was a well-known botanist in her time and was accepted among male botanists.

Jane Colden was born in the province of New York to Cadwallader and Alice (Christy) Colden. She was the fifth of 10 children. When her father learned of her interest in botany, he wrote to a friend, “As it is not usual for woemen [sic] to take pleasure in Botany as a Science I shall do what I can to incourage [sic] her in this amusement which fills up her idle hours to much better purpose tha[n] the usual amusements eagerly pursued by others of her sex” (Beck-Kaplan 2010, 36). This attitude was common at the time. Science was considered a suitable course of study for women because people thought it was unchanging and thus taught obedience to order. Women were particularly encouraged to study botany and astronomy, while men were encouraged to study the classics or law. Maria Mitchell, for example, was the most famed and esteemed astronomer of the pre-Civil War (1861–1865) period but lost some ground after the war as society came to believe that science should be a male-centered field of study. Science books in the 1700s were directed specifically toward women and emphasized that science was an undertaking that could improve the female mind and was preferable to other ways that women could spend their time. The growing popularity of novel reading as a leisure activity for women as well as the increasing affordability of books also led to more scientific books being geared toward women, such as the 1865 *The Young Lady's Geography*.

By 1757, Colden had described and sketched more than 300 local plants. She was known by her contemporaries as an expert botanist regarding species indigenous to New York and her surrounding area. She was also an expert in the Linnaean system of botanical classification. It is apparent from her writings and the writings of her peers that not only was she respected,

but she was also secure in her place as a botanist. If her observations differed from other work in the field, she did not hesitate to say so in her writings. Nonetheless, her father often received the praise and acclaim that should have been directed toward Colden. One example is when Carl Linnaeus, the creator of the Linnaean system, honored Cadwallader Colden, not his daughter, with the new generic plant name *Coldenia*.

During her time working as a botanist, Colden became a skillful plant illustrator and developed a technique for making ink impressions of leaves. She compiled information and illustrations for around 340 plants around the Hudson River Valley. She also joined the Natural History Circle, whose members consisted of both American and European botanists who shared seeds and plant samples with each other. In 1756 she discovered the gardenia, which she named after botanist Alexander Garden. The scientific name was later changed because another plant had been assigned the scientific name *Gardenia*, but the group of flowering plants that Colden identified is still informally called gardenia.

Colden's scientific curiosity in her professional life also showed through to her domestic life. In 1756 she maintained a log of her cheese making. The way that she recorded her efforts here reads much more like a book of experiments than a book of recipes. Colden married Dr. William Farquhar, a physician, on March 12, 1759. The marriage was short-lived because of her death in 1766. Like many women of her time, Colden died during the birth of their first child, who died within the week as well.

After Colden's death and during the American Revolutionary War, a Hessian captain found her drawings and plant descriptions. He returned to England with them, and now they are held at the British Museum. In 1963, the American Garden Clubs published part of the manuscript. Colden's unnamed manuscript is still prized today for its artistry and accuracy.

Elliott Popel

See also Vol. 1, Sec. 3: Mitchell, Maria

Further Reading

Beck-Kaplan, Colleen. 2010. “Family of Science: Education, Gender, and Science in the Colden Family of New York 1720–1770.” Electronic Theses, Treatises and Dissertations, Florida State

University Libraries. <http://diginole.lib.fsu.edu/islandora/object/fsu:175740/datastream/PDF/view>, accessed August 22, 2018.

Bonta, Marcia. 1991. *Women in the Field: America's Pioneering Women Naturalists*. College Station: Texas A&M University Press.

Robbins, Paula Ivaska. 2009. *Jane Colden: America's First Woman Botanist*. Fleischmanns, NY: Purple Mountain.

Daylight Saving Time

Even though Daylight Saving Time (DST) has been in use for the past century, it was conceived by ancient civilizations that adjusted their daily schedules to the sun's schedule. For example, Roman water clocks used different scales for different months of the year. American inventor and statesman Benjamin Franklin was the first to formally propose DST to save energy and make better use of daylight. He wrote an essay titled "The economical project for diminishing the cost of light" to the editor of the *Journal of Paris* in 1794, where he suggested that Parisians could economize on candle usage by getting out of bed earlier, making use of the morning light instead.

Franklin calculated that using seven hours of candlelight for 183 nights between March 20 and September 20 equaled 1,281 hours for a half year of candle usage. Multiplying by 100,000 Parisian families gave 128,100,000 hours by candlelight. 64,050 pounds of tallow and wax were required, since each candle required a half pound of them. He calculated the total cost of burning a candle to be 96,075,000 *livres tournois*, "an immense sum that the city of Paris might save every year." Hence, Franklin proposed regulations such as levying a tax on every window built with shutters to keep out the light of the sun, rationing candles to one pound per family per week, and having the regulation enforced by constabulary. Guards were to be posted to stop the passage of all coaches upon the streets after sunset except those of physicians, surgeons, and midwives. He further suggested that at dawn, church bells, and, if necessary, cannon should inform the citizenry of the advent of light: "Oblige a man to rise at four in the morning, and it is possible he will go willingly to bed at eight in the evening."

The idea of DST was popularized much later—during World War I, when nations aimed to conserve energy and minimize the use of artificial lighting to save fuel for the war effort. Germany was the first country to introduce DST, when clocks were turned one hour ahead on April 30, 1916. The idea was quickly accepted by the United Kingdom, followed by France. In the United States, DST was first introduced in 1918 when President Woodrow Wilson signed it into law. It was repealed seven months later but reinstituted during World War II (between February 9, 1942, and September 30, 1945), in the United States and Canada. The United Kingdom applied "Double Summer Time" during this period by setting clocks two hours ahead of GMT during summer and one hour ahead of GMT during the winter.

Between 1945 and 1966, there were no uniform rules for DST in the United States, and this caused widespread confusion, especially for trains, buses, and the broadcasting industry. Consequently, Congress established the Uniform Time Act of 1966, which stated that DST would begin on the last Sunday of April and end on the last Sunday of October. During the energy crisis of the early 1970s, Congress extended DST to a period of 10 months in 1974 and 8 months in 1975, saving the equivalent of 10,000 barrels of oil each day, but the program remained controversial. Between 1987 and 2006, the United States observed about seven months of DST each year. The current eight-month schedule was introduced in 2007 and follows the Energy Policy Act of 2005. Now DST starts on the second Sunday in March and ends on the first Sunday in November.

DST is now in use in over 70 countries and affects over a billion people every year. The beginning and end dates vary from country to country. In 1996, the European Union (EU) standardized an EU-wide DST schedule, which runs from the last Sunday in March to the last Sunday in October.

Abhijit Roy

See also Franklin, Benjamin

Further Reading

Prerau, D. 2009. *Seize the Daylight: The Curious and Contentious Story of Daylight Saving Time*. New York: Basic Books.

Extension Arm (Long Arm)

Benjamin Franklin invented the extension or long arm in 1786 when he was 80 years old. After his final trip abroad, returning to Philadelphia in 1785 after serving as the U.S. minister to France, he had accumulated a large collection of books in his home library. Earlier, in 1731, he had composed the charter for the Library Company of Philadelphia.

Franklin liked to spend time with books and particularly enjoyed the Philadelphia library, but reaching books on high shelves continued to be a challenge, particularly during his later years. Hence, he devised a simple extension arm or “long arm.” The device had a grasping claw consisting of two “fingers” that were attached at the end of a long piece of wood or pipe. These fingers could be opened or closed by pulling on a cord. This tool allowed Franklin to retrieve books located three to four feet higher than he was normally able to reach.

Franklin wrote about the tool to his nephew John Williams in a letter dated February 12, 1786, in which he noted the practical utility of his latest invention.

This was a simple, clever yet resourceful tool that could be used for fetching not only books but other objects as well. Derivatives of this concept are still used today. This is very similar to the “grabber” arm that is common today for both in-home and outdoor use. Modern incarnations of the extension arm are helpful in bringing down high-placed items, particularly in supermarkets and in homes, where they are often used by older persons. Extension arms called “trash grabbers” are handy for use in outdoor settings, allowing the user to pick up trash without bending over again and again. Few modern users know that they can thank Benjamin Franklin for this handy tool.

Abhijit Roy

See also Franklin, Benjamin

Further Reading

McDonough, Yona Zeldis. 2006. *The Life of Benjamin Franklin: An American Original*. New York: Macmillan.

PBS. “Inquiring Mind.” www.pbs.org/benfranklin/l3_inquiring_little.html, accessed August 22, 2018.

Fire Safety

While the notion of fire safety spans all the way back to the Roman Empire after the Great Fire of Rome in 64 CE, modern American fire safety did not exist until 1631, when John Winthrop established a building code to outlaw thatched roofs and wooden chimneys. This was the first means of fire prevention, one of several key areas of fire safety, and was expanded in 1648 to allow for fire wardens, who would inspect buildings and could issue fines to homeowners for negligence. However, paid firefighters did not come about until nearly 30 years later, after a major fire in Boston.

The First Union Fire Company, established by Ben Franklin in 1736, was the first volunteer fire department. It was not until the Great Chicago Fire (1871), the Great Peshtigo Fire (1871), and the Great Boston Fire (1872) happened in rapid succession that major changes to the fire codes and other fire safety developments occurred.

After these three major fires, a sprinkler system, which had been originally designed in 1812, was built upon by Henry S. Parmalee to be automatic. Joseph Grinnell further developed this system until eventually, in 1890, the glass disk sprinkler head had been created, a system that is still used today. At the turn of the 20th century, the most deadly theater fire in American history occurred at the Iroquois Theater in Chicago. After the tragedy, the federal government created requirements for exit pathways, door size, and exit sign markings, plus maximum occupancy laws. A fire in Baltimore in 1904 led to the creation of a national standard for fire hose sizes, and the General Slocum Water Boat Fire in New York caused an improvement on safety equipment after 1,030 people died when archaic and degrading equipment failed.

Perhaps the most influential fire, the Triangle Shirtwaist Factory Fire in 1911, established the need for fire exits from buildings several stories high after many women jumped from buildings to escape danger. Fires in the 1940s resulted in a refinement of the safety codes to include revolving doors, a standard for the number of fire exits in a building, fire-resistant exit structures, and the development of a fire alarm. In 1958, a school fire caused the implementation of school regulations to protect students. When firefighters in Los Angeles noted that the spread of fire was rapid when wind speeds were high, shingled roofs became a requirement.

In 1967, a major fire claimed the lives of three Apollo 1 astronauts. The tragedy resulted in preemptive increased safety standards for commercial airplanes. The next major breakthrough in fire safety was in 1980, after the MGM Hotel caught fire in Las Vegas. This fire brought about the discovery that smoke can kill just as easily as fire itself can. In the following decades, smoke detectors have become a more common requirement, with CO₂ often being integrated into a smoke alarm as well. Improved fire safety codes are aimed at reducing loss of life due to lack of foresight in building construction.

Cassady O'Reilly-Hahn

See also Franklin, Benjamin

Further Reading

- Milke, James, and Robin Zevotek. 2016. "Analysis of the Response of Smoke Detectors to Smoldering Fires and Nuisance Sources." *Fire Technology* 52, no. 5: 1235–53.
- Reisinger, K. S. 1980. "Smoke Detectors: Reducing Deaths and Injuries Due to Fire." *Pediatrics* 65, no. 4: 718.
- Santer, Lisa J., and Carol B. Stocking. 1991. "Safety Practices and Living Conditions of Low-Income Urban Families." *Pediatrics* 88, no. 6: 1112.

Flexible Catheter

Benjamin Franklin invented the flexible catheter in 1752. Prior to his invention, catheters were hard tubes jammed into the bladder through the urethra, primarily rigid (and painful) metal ones. His invention was precipitated by the fact that one of his older brothers, John, suffered from kidney stones and had to undergo an excruciating daily ritual of using a bulky metal catheter.

John wrote to Franklin from Boston, complaining about problems with urinating due to bladder stones. Franklin wrote back that he had an idea for a flexible catheter and how one might be made. He further informed John that he had given his directions to a silversmith, who made a model for him.

A follow-up letter from Franklin to his brother in January 1753 suggests that John did show some

near-term improvement by injecting liquids containing lye through the flexible catheter to dissolve the stones. Franklin wrote back to John, saying that he was happy to be informed that he was better. John lived for an additional four years after receiving the new catheter.

Franklin's flexible catheter was a much more practical and less painful solution than the rigid tube that doctors had been using. It was made from silver wire coiled with joints to allow the flexibility of hinged metal segments. Franklin himself later needed the flexible catheters, as he suffered from episodes of gout and eventually complained of urinary difficulties that were probably due to a uric acid bladder stone.

This type of catheter was a major improvement on existing ones. Aulus Celsus, a Roman encyclopedist living in the first century, mentioned in his *De Medecina* that bronze catheters had been found in the rubble of Pompeii. Catheters were made of metal until the 11th century and were difficult to insert, hence extremely uncomfortable. Avicenna (980–1037) described the first primitive flexible catheters, which were made of animal skins treated with agents to make them firm enough for insertion after lubrication. Fabricus ab Acquapendente, who lived in Italy in the early 17th century, used a horn that would soften when left in place, as well as a tube of cloth impregnated with wax. Yet these innovations were not very satisfactory.

In the late 1600s, a Dutch surgeon named van Solingen made a flexible catheter of wound silver wire that was covered with soft animal skin and treated with wax. Early in the 18th century, Francesco Roncalli Parolino made further advancements in building a flexible catheter by covering a fine, thin spiral tube with fine skin and later silk. Franklin did not mention any of these European devices or their inventors in his writings, and so it is difficult to ascertain how much they influenced his innovation. Yet he is the one who had introduced the most modern of flexible catheters (until then) in the American colonies.

Much more advanced versions of the flexible catheter are used today. Although it wasn't the most sophisticated device that Franklin invented, it was very popular in America at that time and was a welcome relief for hundreds of people with bladder problems.

Abhijit Roy

See also Franklin, Benjamin

Further Reading

- Corner, George W., and Willard E. Goodwin. 1953. "Benjamin Franklin's Bladder Stone." *Journal of the History of Medicine and Allied Sciences* 8 (October): 359–77.
- Finger, Stanley. 2006. *Doctor Franklin's Medicine*. Philadelphia: University of Pennsylvania Press.
- Kardeh, Sina, Rasool Choopani, Golnoush Nezhad, and Arman Zargar. 2014. "The Urinary Catheter and Its Significant Applications Described by Avicenna (980–1037 AD) in the Canon of Medicine." *Urology* 84, no. 5 (November): 993–96.
- Murphy, Leonard. 1972. *The History of Urology*. Springfield, IL: Charles C. Thomas.
- Nacey, John, and Brett Delahunt. 1993. "The Evolution and Development of the Urinary Catheter." *Australian and New Zealand Journal of Surgery* 63, no. 10: 815–19.
- Pepper, William. 1911. *The Medical Side of Benjamin Franklin*. New York: W. J. Campbell.

Food Production, Native American

In North America prior to European contact, Native American women held equal status with men, because gender-specific occupational roles gave women control over food and vital resources. Native American societies varied in organization, language, belief systems, and cultural practices. However, most of these hunter-gather and hunter-agricultural societies practiced what anthropologists call "gender complementarity": women and men complemented each other by doing different jobs, thereby enabling the group as a whole to find and process the most available food.

In many cultures, women gathered wild plant foods: leafy plants, seaweed, berries, roots, nuts, and seeds. Successful gathering required botanical knowledge of plant location, the best collection period, and specific preparation. Mothers and female relatives began teaching girls gender-specific knowledge when they reached eight years old. Girls learned plant identification and processing: baking and drying roots and drying and grinding grains. Once dried, food staples could be stored and reconstituted in a stew or porridge

or baked as a cake or bread. Meat and other vegetables were added to these staples.

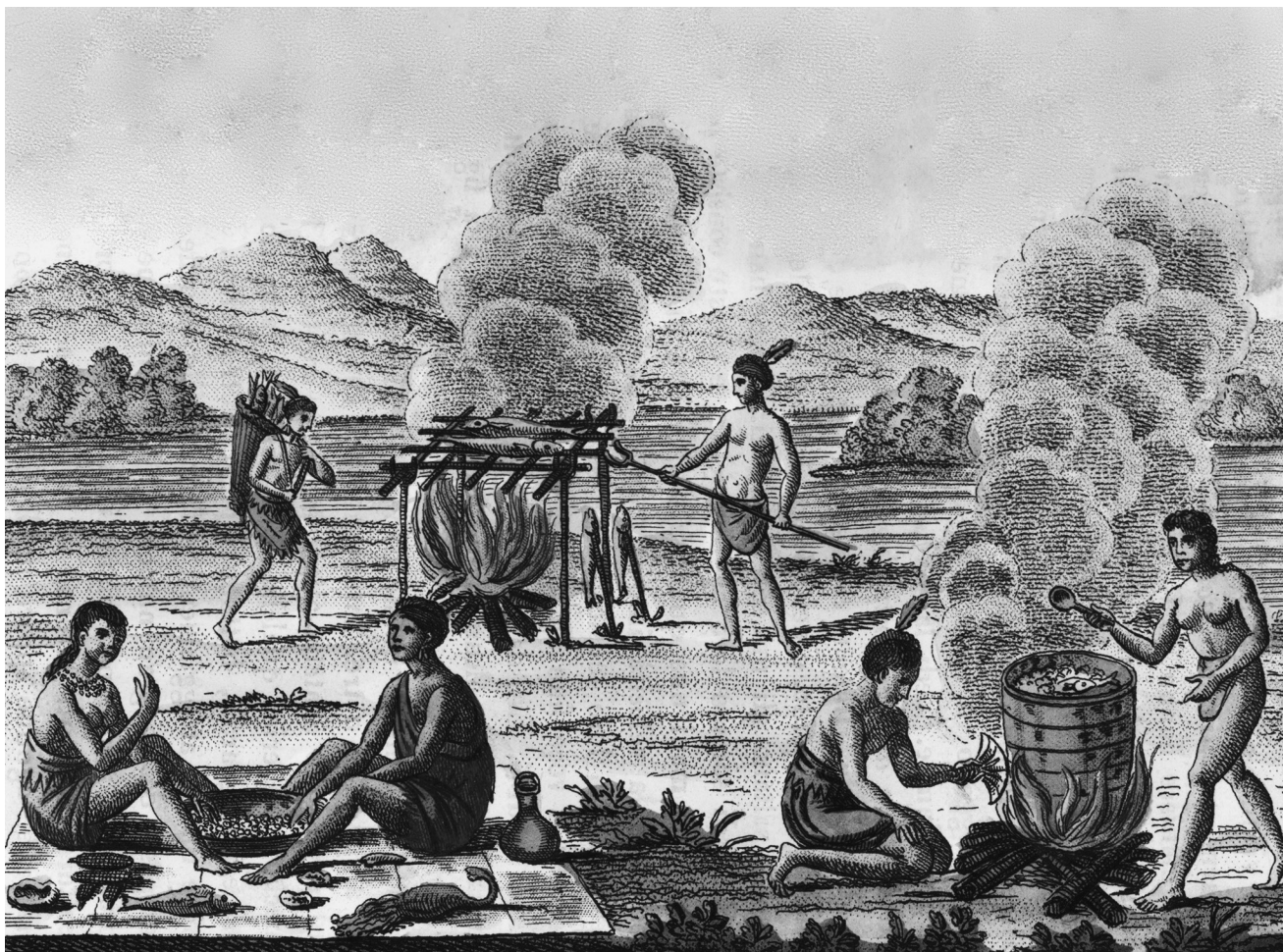
Some resources, such as acorns, required skilled preparation to make them safe for eating. The camas bulb, gathered on the northwestern plateau, required expertise to distinguish edible from poisonous bulbs. Among these people, young girls demonstrated advancement into womanhood by successfully collecting edible camas and preparing it for tribal elders, a ceremonial equivalent to a boy's first hunt. Sacagawea's knowledge of camas and other roots saved the Lewis and Clark Expedition from deprivation.

Women made tools for their own horticultural use. Digging sticks served to unearth wild roots and plant seeds. Storing and processing food required containers; therefore, girls learned basketry, pottery, and leather working.

Women originated farming technology and typically grew agricultural crops. Gourds, sunflowers, and goosefoot or quinoa were North American crop plants. Women in Mexico and Central America developed melons, chilies, squash, beans, and maize. Prior to European arrival, these crops were grown by peoples from the Anasazi and Pueblo cultures of the Southwest to the Iroquois Confederacy in the Northeast. Food surpluses produced by women increased native populations and enabled semipermanent villages and large civic complexes. The women who produced these foods held high or equivalent social positions with men, who provided large-game protein.

The Iroquois identified maize, beans, and squash as distinctively feminine icons known as the "Three Sisters." Eaten together, these staples provided a nutritionally well-balanced diet. The three plants also nurtured each other: the squash shaded the maize's roots, the maize provided a stalk for the beans to climb, and the beans replenished the soil with nitrogen for its sisters.

Women developed maize into a high-yield crop essential to community well-being. Many cultures integrated maize into their religions, celebrating planting and/or harvesting in the Green Corn Ceremony. The Corn Mother and other feminine spirits honored fertility, regeneration, and the vital role of women. In most cultures, women managed agricultural lands and transferred farming or gathering rights through matrilineal descent (from mother to daughter).



Native Americans grill and roast fish and boil meat with hominy, while a couple sits on a mat, eating from a plate between them. (Florilegius/SSPL/Getty Images)

Women controlled their harvest and in many cultures could barter or sell any excess food they produced. In addition, the tools and containers a woman made were her individual property. Food production provided women with independent economic power within their communities. Contrary to the views of Europeans who documented encounters with native peoples, Native American women were not performing drudgery work for their husbands; they were managing their own agricultural enterprises. Male occupations included hunting large game and fishing, but women frequently captured small game—voles, prairie dogs, and rabbits—in plant fiber nets or snares. Gender roles did not bar a skilled woman from hunting. Some women's graves within mound-building cultures have been found to contain personal hunting paraphernalia: stone balancing weights for a spear-tossing implement called

an "atlatl." Similarly, a man could act in a female role. Female and male genders complemented each other, and therefore both were valued.

Men hunted caribou, bison, and deer, while women typically processed the carcasses—skinning them, cutting up the flesh, and drying or smoking the meat. Prey such as salmon and bison were harvested in vast quantities in short bursts of time. In such situations, community members worked together to secure the greatest resource abundance. Women with expertise fished, and men assisted women in smoking salmon and butchering bison. Women did not prepare or process food during their menstrual cycles. Menses was a time of spiritual introspection; other family members then handled that woman's everyday tasks.

Among the Iroquois, the clan mother made sure that clan members (extended matrilineal relatives)

received enough food. Even in cultures where women did not butcher meat, they typically distributed meat resources. Control over food gave women social and economic power. Among the Senecas of the Iroquois Confederacy, women provisioned warriors. They could not stop male warfare, but they could refuse to provide food supplies, effectively curtailing a war party.

Management of food resources yielded personal autonomy. Women who controlled their own resources were independent and usually free to divorce. Some female English captives, such as Mary Jemison, stayed within Native American societies because they experienced greater personal autonomy there.

When Europeans influenced Native American men to become farmers or imposed food resources on native societies, they changed the economic status of women within these societies. Without control over food resources, women's political power diminished. The social imbalance created by the loss of complementarity was destructive to Native American societies and caused a decline in female social status within tribal cultures through the 20th century.

Keri Dearborn

See also *Vol. 1, Sec. 2: Lewis and Clark Expedition*

Further Reading

- Adovasio, J. M., Olga Soffer, and Jake Page. 2007. *The Invisible Sex: Uncovering the True Roles of Women in Prehistory*. New York: HarperCollins.
- Bruhns, Karen Olsen, and Karen E. Stothert. 1999. *Women in Ancient America*. Norman: University of Oklahoma Press.
- Klein, Laura F., and Lillian A. Ackerman. 1995. *Women and Power in Native North America*. Berkeley: University of California Press.

Franklin, Benjamin (1706–1790)

He was never president of the United States, but Benjamin Franklin influenced the transformation of 13 separate colonies to a new nation. He is remembered as a statesman, writer, and inventor. He was the only Founding Father to sign the Declaration of Independence (1776), the Treaty of Alliance with France (1778),

the Treaty of Paris (1783), and the United States Constitution (1787).

Franklin was born in 1706 in Boston, Massachusetts. His father, Josiah Franklin (1657–1745) was a soap maker and candle maker. Abiah Folger (who died in 1744) was his mother. He attended Boston Latin School for two years. When he was 10 years old, he left school to work for his father.

Franklin's brother, James, was nine years older than he was and worked as a printer. When Franklin was 12, he was apprenticed to James. James founded the weekly newspaper *The New England Courant* in 1721. Franklin submitted letters to the *Courant*, but James refused to print them. Franklin changed his handwriting and using the pen name "Silence Dogood" to submit humorous letters written by a fictional middle-aged widow. The letters were very popular.

James was arrested in 1722 for publishing unflattering remarks about the governor and was jailed, without trial, for three weeks, during which time Franklin ran the newspaper. Franklin and James's relationship was strained, and Franklin left the apprenticeship without his brother's permission.

Franklin left Boston and went to Philadelphia when he was 17. He worked in print shops to support himself. There, Franklin met Deborah Read (c. 1708–1774). He planned to go to London so he proposed to her, but her mother refused the match. Franklin sailed to London and worked as a printer. Deborah's mother convinced her to marry another man—who deserted her a few months after they were married.

Franklin returned to Philadelphia in 1726. Since Deborah was unable to marry him, she became Franklin's common-law wife in 1730. They remained together until her death in 1774 and had two children: Francis (1732–1736) and Sarah "Sally" (1743–1808). The couple also raised Franklin's illegitimate son, William (1730–1813).

Franklin formed a group of tradesmen and artisans who met to discuss topics of the day and books. This "junto" group, as he called it, began in 1727. Books were expensive and hard to get, so the members combined their books and borrowed them from each other. This idea developed into pooling members' money to buy books for the group's borrowing. This idea of a lending library led to the Library Company of Philadelphia being founded in 1731.

Franklin published the first *Poor Richard's Almanack* in late 1732 using the pen name Richard Saunders. Saunders and his wife, Alice Addertongue, offered folksy humor and poked fun at pretentious snobs as well as everyday people. It also contained proverbs and sayings. Franklin wrote for the *Almanack* for 25 years.

Franklin organized one of the first volunteer fire departments in America: the Union Fire Company was formed in 1736.

Franklin was always curious and developed a variety of innovations. He invented a mechanical arm to retrieve books from high shelves (and also replace them). Among his many inventions were bifocal glasses (each lens has two optical powers) and the Franklin stove (it had a metal liner that produced more heat and less smoke).

He experimented with electricity. His experiments led to the invention of the lightning rod in 1750. It was an iron rod that was attached at the top of a structure; a wire ran from the rod to the ground. If lightning struck the rod, the electricity would go down it and then the wire, to be dispersed in the ground. His work with electricity earned him honorary degrees from Harvard and Yale in 1753.

Franklin's political career began in 1748, when he served as a Philadelphia councilman. He then served as a justice of the peace and in 1751 was elected to the Pennsylvania Assembly. He helped organize the Pennsylvania Militia in 1756.

The Pennsylvania Assembly sent Franklin to London in 1757 as colonial agent to represent the colony's interests. He didn't return to Philadelphia until 1763.

Franklin remained influential in Pennsylvania politics. The Assembly chose him as one of its delegates to the Second Continental Congress in 1775. He was

one of five delegates selected to help draft the Declaration of Independence.

Franklin was chosen as commissioner for the United States to France in 1776. He negotiated the Treaty of Paris, which ended the Revolutionary War in 1783. Though never president of the United States, in 1785, he did become president of Pennsylvania, a post equivalent to governor. He served several terms. He also served as a delegate to the Constitutional Convention held in Philadelphia in 1787.

Franklin's health declined as he aged. He suffered from obesity and gout for many years and died in 1790 in Philadelphia.

To say that Franklin was a man of many talents would be an understatement. Most people would be happy to have achieved even one of his accomplishments. Benjamin Franklin is remembered for his wit, his imagination, his inventions, and as a founder of the United States of America.

Linda Briley-Webb

See also Franklin Stove; Glass Harmonica (Armonica); *Vol. 1, Sec. 2*: Jefferson, Thomas; *Vol. 2, Sec. 1*: Stethoscope, Binaural

Further Reading

Isaacson, Walter. 2003. *Benjamin Franklin: An American Life*. New York: Simon & Schuster.

Lee, Mike. 2017. *Written Out of History: The Forgotten Founders Who Fought Big Government*. New York: Sentinel.

Williamson, Rana, ed. 1999. *American History*. Bath: Paragon.

Primary Document: Letter of Benjamin Franklin Describing His Experiments with Electricity (c. 1750)

In 1751, the Royal Society arranged for the publication of a series of letters from Benjamin Franklin, written between 1747 and 1750, describing his experiments with electricity. Franklin demonstrated his new theory of positive and negative charges, suggested the electrical nature of lightning, and proposed a tall, grounded rod as a protection against lightning. The following are excerpts from a letter in

which Franklin describes his efforts to electrocute a turkey.

I have lately made an Experiment in Electricity that I desire never to repeat. Two nights ago, being about to kill a turkey by Shock from two large glass Jars containing as much electrical fire as forty common Phials, I inadvertently took the whole thro' my

own Arms and body. . . . The Company present (whose talking to me and to on another I suppose occasioned my Inattention to what I was about) say that the flash was very great and the crack as loud as a pistol; yet my Senses being instantly gone, I neither Saw the one nor heard the other; nor did I feel the Stroke on my hand, tho' I afterwards found it raised a round swelling where the fire entere'd as big as a half a Pistol Bullett by which you may judge the Quickness of Electrical Fire. . . .

I then felt what I know not how well to describe; as universal Blow thro'out my whole Body from head to foot which seem'd within as well as without; after which the first thing I took notice of was a violent quick Shaking of my body which gradually remitting, my sense as gradually return'd, and then I tho't the

Bottles must be discharged but Could not conceive how, till att last I Perceived the Chain in my hand, and Recollected what I had been About to do: that part of my hand and fingers which held the Chain was left white as tho' the Blood had been Driven Out, and Remained so 8 or 10 Minutes After, feeling like Dead flesh, and I had a Numbness in my Arms and the back of my Neck, which Continued till the Next Morning but wore off. Nothing Remains now of this Shock but a Soreness in my breast Bone, which feels As if it had been Bruised. I Did not fall, but Suppose I should have been Knocked Down if I had Received the Stroke in my head: the whole was Over in less than a minute.

Source: Benjamin Franklin's letter to his brother John Franklin, December 25, 1750. Original housed in Winthrop Family Papers, Massachusetts Historical Society.

Franklin Stove

The Franklin stove was invented by Benjamin Franklin in 1742. It was a metal-lined fireplace that was situated in the center of a room. This wood-burning stove provided more heat with less fuel and hence less smoke. Its cast-iron furnace was designed to radiate heat from the middle of the room in all directions, while the iron walls absorbed heat, providing warmth to the room much longer after the fire went out. Such fireplaces helped save wood and were used in many houses in Pennsylvania as well as in other neighboring colonies. It was also called the "circulating stove" or the "Pennsylvania fireplace."

Franklin's design idea for the stove that provided more heat and less smoke was based on two books by Jean Théophile Desaguliers (1683–1744), a French immigrant to England. He also incorporated new scientific concepts about heat developed by the Dutch physician Herman Boerhaave (1688–1738), a proponent of Isaac Newton's ideas. The stove was approximately 30 inches tall with a box shape. The front side was open except for a decorative panel in the upper part of the box. The back of the box was placed a few inches away from the flue or chimney. These panels were bolted together with iron screws through precast ears. The smoke was forced into the holes through small, thin rectangular prisms inside the panels.

The two key features of the Franklin stove were: (a) a hollow baffle or a metal panel that directed the flow of the fire's fumes downward, and (b) a flue that acted as an inverted siphon. Franklin called the inverted siphon an "aerial syphon" or "syphon reversed." Cool air entered the baffle through a duct under the floor, while smoke exited through a U-shaped duct in the floor. The hollow baffle was positioned inside and near the rear of the stove. It performed two critical functions: it lengthened the path that the fire's fumes had to follow before reaching the chimney, allowing more heat to be extracted from the fumes, and the duct placed near the fire helped heat the room's air via convection.

Franklin initially presented a model of the stove to a friend, Robert Grace, and tried to promote it with a pamphlet called *An Account of the New Invented Pennsylvanian Fire-Places*, in which he explained the construction and manner of operation of the stove and why it was the best method for warming rooms. The deputy governor of Pennsylvania, George Thomas, offered Franklin the patent of this design and invention, but he refused because he believed that "as we enjoy great advantages and inventions of others, we should be glad of an opportunity to serve others by any invention of ours, and this we should do freely and generously."

Hence, several others were able to use his design and improve it. An ironmonger in London followed

the instructions from the pamphlet, made minor adaptations to the machine, and patented it in England. When Franklin was in London to represent the colonies during the American Revolution, he was approached by Filippo Mazzei, an Italian businessman looking to buy a proper Franklin stove. It was then that Franklin discovered how many variations of his stove existed. The experience formed a friendship that aided the Colonies further. Mazzei became America's representative in Europe, soliciting funds and support for the war against Britain.

Even though the original goal of the stove was for the dual purpose of cooking and heating a room, over time, the Franklin stove was primarily used for heating. After some initial enthusiasm, the stove's sales tapered off. The primary problem was with the inverted siphon—the smoke had to pass through a cold flue set in the floor before it could enter the chimney; hence, the stove did not have a good draft since the smoke cooled too much. The inverted siphon operated properly only when the fire burned constantly so that the temperature in the flue was high enough to produce a draft. David Rittenhouse later designed a much-improved version that eliminated

several of the problems in Franklin's stove, and it also became popular. Yet, Franklin's version is better remembered because of its pioneering features. Even today, most wood-burning stoves in the United States are box-shaped like the original Franklin stove.

Abhijit Roy

See also Franklin, Benjamin; Rittenhouse, David

Further Reading

Binder, Frederick M. 1958. "Anthracite Enters the American Home." *Pennsylvania Magazine of History and Biography* 82, 82–99.

Edgerton, Samuel Y., Jr. 1990. "The Franklin Stove," Supplement to I. In *Benjamin Franklin's Science*, edited by Bernard Cohen, 199–211. Cambridge: Harvard University Press.

Franklin, Benjamin. 1744. *An Account of the New Invented Pennsylvanian Fire-Places*. Philadelphia: Printed and sold by B. Franklin (Yale University Library).

Wright, Esmond. 1988. *Franklin of Philadelphia*. Cambridge, MA: Harvard University Press.

Primary Document: Excerpt from Benjamin Franklin's *An Account of the New Invented Pennsylvanian Fire-Places* (1744)

Benjamin Franklin published An Account of the New Invented Pennsylvanian Fire-Places in 1744 to describe a new kind of heating system. In the excerpt here, he explains how fireplaces work as well as common types of fireplaces and their deficiencies.

IN these Northern Colonies the Inhabitants keep FIRES to sit by, generally *Seven Months* in the Year; that is, from the Beginning of October to the End of April; and in some Winters near *Eight Months*, by taking in part of September and May.

WOOD, our common Fewel, which within these 100 Years might be had at every Man's Door, must now be fetch'd near 100 Miles to some Towns, and makes a very considerable Article in the Expence of Families.

As therefore so much of the Comfort and Conveniency of our Lives, for so great a Part of the Year, depends on the Article of FIRE; since Fuel is become so expensive, and (as the Country is more clear'd and settled) will of course grow scarcer and

dearer; any new Proposal for Saving the Wood, and for lessening the Charge and augmenting the Benefit of FIRE, by some particular Method of Making and Managing it, may at least be thought worth Consideration.

THE NEW FIRE-PLACES are a late Invention to that purpose (experienced now three Winters by a great Number of Families in Pennsylvania) of which this Paper is intended to give a particular Account.

THAT the Reader may the better judge whether this Method of Managing Fire has any Advantage over those heretofore in Use, it may be proper to consider both the old and new Methods separately and particularly, and afterwards make the Comparison.

IN order to this, 'tis necessary to understand well some few of the Properties of AIR and FIRE, viz.

1. AIR is rarified by *Heat*, and condens'd by *Cold*; i.e. the same Quantity of Air takes up more Space when warm than when cold. This may be

shown by several very easy Experiments. Take any clear Glass Bottle (a Florence Flask stript of the Straw is best) place it before the Fire, and as the Air within is warm'd and rarified, part of it will be driven out of the Bottle; turn it up, place its Mouth in a Vessel of Water, and remove it from the Fire; then, as the Air within cools and contracts, you will see the Water rise in the Neck of the Bottle, supplying the Place of just so much Air as was driven out. Hold a large hot Coal near the Side of the Bottle, and as the Air within feels the Heat, it will again distend and force out the Water. Or, Fill a Bladder half-full of Air, tie the Neck tight, and lay it before a Fire as near as may be without scorching the Bladder; as the Air within heats, you will perceive it to swell and fill the Bladder, till it becomes tight as if full-blown: Remove it to a cool Place, and you will see it fall gradually, till it become as lank as at first.

2. AIR rarified and distended by Heat, is specifically lighter than it was before, and will rise in other Air of greater Density. As Wood, Oil, or any other Matter specifically lighter than Water, if plac'd at the Bottom of a Vessel of Water, will rise till it comes to the Top; so rarified Air will rise in common Air, till it either comes to Air of equal Weight, or is by Cold reduc'd to its former Density.

A FIRE then being made in any Chimney, the Air over the Fire is rarified by the Heat, becomes lighter and therefore immediately rises in the Funnel and goes out; the other Air in the Room (flowing towards the Chimney) supplies its Place, is rarified in its turn, and rises likewise; the Place of the Air thus carried out of the Room is supplied by fresh Air coming in thro' Doors and Windows, or, if they be shut, thro' every Crevice with Violence, as may be seen by holding a Candle to a Keyhole: If the Room be so tight as that all the Crevices together will not supply so much Air as is continually carried off, then in a little time the Current up the Funnel must flag, and the Smoke being no longer driven up must come into the Room.

1. FIRE throws out Light, Heat, and Smoke (or Fume). The two first move in right Lines and with great Swiftmess; the latter is but just separated from the Fuel, and then moves only as it is carried by the Stream of rarified Air. And

without a continual Accession and Recession of Air to carry off the Smoaky Fumes, they would remain crouded about the Fire, and stifle it.

2. HEAT may be separated from the Smoke as well as from the Light, by means of a Plate of Iron, which will suffer Heat to pass through it without the others.
3. FIRE sends out its Rays of Heat, as well as Rays of Light, equally every way: But the greatest sensible Heat is over the Fire, where there is, besides the Rays of Heat shot upwards, a continual rising Stream of hot Air, heated by the Rays shot round on every Side.

THESE Things being understood, we proceed to consider the Fire-places heretofore in Use, viz.

1. The large open Fire-places used in the Days of our Fathers, and still generally in the Country, and in Kitchens.
2. The newer-fashion'd Fire-places, with low Breasts, and narrow Hearths.
3. Fire-places with hollow Backs, Hearths and Jams of Iron, (described by Mons. Gauger) for warming the Air as it comes into the Room.
4. The Holland Stoves, with Iron Doors opening into the Room.
5. The German Stoves, which have no Opening in the Room where they are us'd, but the Fire is put in from some other Room, or from without.
6. Iron Pots, with open Charcoal Fires, plac'd in the middle of a Room.
1. The first of these Methods has generally the Conveniency of two warm Seats, one in each Corner; but they are sometimes too hot to abide in, and at other times incommoded with the Smoke; there is likewise good Room for the Cook to move, to hang on Pots, &c. Their Inconveniencies are, that they almost always smoke if the Door be not left open; that they require a large Funnel, and a large Funnel carries off a great Quantity of Air, which occasions what is called a strong Draft to the Chimney; without which strong Draft the Smoke would come out of some Part or other of so large an Opening, so that the Door can seldom be shut; and the cold Air so nips the Backs and Heels of those that sit before the Fire, that they have no Comfort, 'till either Screens or Settles are provided

(at a considerable Expence) to keep it off, which both cumber the Room and darken the Fireside. A moderate Quantity of Wood on the Fire in so large a Hearth, seems but little; and, in so strong and cold a Draught, warms but little; so that People are continually laying on more. In short, 'tis next to impossible to warm a Room with such a Fire-place: And I suppose our Ancestors never thought of warming Rooms to sit in; all they purpos'd was to have a Place to make a Fire in, by which they might warm themselves when acold.

2. MOST of these old-fashion'd Chimneys in Towns and Cities, have been, of late Years, reduc'd to the second Sort mention'd, by building Jambs within them, narrowing the Hearth, and making a low Arch or Breast. 'Tis strange, methinks, that tho' Chimneys have been so long in Use, their Construction should be so little understood till lately, that no Workman pretended to make one which should always carry off all the Smoke, but a Chimney-cloth was look'd upon as essential to a Chimney: This Improvement, however, by small Openings and low Breasts, has been made in our Days; and Success in the first Experiments has brought it into general Use in Cities, so that almost all new Chimneys are now made of that sort, and much fewer Bricks will make a Stack of Chimneys now than formerly. An Improvement so lately made, may give us Room to believe that still farther Improvements may be found, to remedy the Inconveniencies yet remaining. For these new Chimneys, tho' they keep Rooms generally free from Smoke, and, the Opening being contracted, will allow the Door to be shut, yet the Funnel still requiring a considerable Quantity of Air, it rushes in at every Crevice so strongly, as to make a continual Whistling or Howling; and 'tis very uncomfortable as well as dangerous to sit against any such Crevice. Many Colds are caught from this Cause only; it being

safer to sit in the open Street; for then the Pores do all close together, and the Air does not strike so sharply against any particular Part. The Spaniards have a Proverbial Saying, *If the Wind blows on you thro' a Hole, Make your Will, and take Care of your Soul*. Women, particularly, from this Cause, (as they sit much in the House) get Colds in the Head, Rheums and Defluctions, which fall into their Jaws and Gums, and have destroy'd early many a fine Set of Teeth in these Northern Colonies. Great and bright Fires do also very much contribute to damage the Eyes, dry and shrivel the Skin, and bring on early the Appearances of Old-Age. In short, many of the Diseases proceeding from Colds, as Fevers, Pleurisies, &c. fatal to very great Numbers of People, may be ascrib'd to strong-drawing Chimneys, whereby, in severe Weather, a Man is scorch'd before, while he's froze behind. In the mean time very little is done by these Chimneys towards warming the Room; for the Air round the Fire-place which is warm'd by the direct Rays from the Fire, does not continue in the Room, but is continually crouded and gather'd into the Chimney by the Current of cold Air coming behind it, and so is presently carried off.

In both these Sorts of Fire-places, the greatest Part of the Heat from the Fire is lost: For as Fire naturally darts Heat every way, the Back, the two Jambs, and the Hearth, drink up almost all that's given them, very little being reflected from Bodies so dark, porous and unpolish'd; and the upright Heat, which is by far the greatest, flies directly up the Chimney. Thus Five Sixths at least of the Heat (and consequently of the Fewel) is wasted, and contributes nothing towards warming the Room.

Source: Franklin, Benjamin. 1744. *An Account of the New Invented Pennsylvanian Fire-Places*. Philadelphia: Printed and Sold by B. Franklin. National Archives.

Glass Harmonica (Armonica)

Benjamin Franklin created the first glass harmonica in 1761. It was his favorite invention. It was a mechanized version of a popular entertainment in England in the

early 18th century made famous by Richard Pockridge (1690–1759) and Christoph Glück (1714–1787) that involved playing music on upright wine goblets, with tones made by rubbing one's fingers around the lips of glasses filled with different quantities of fluid.

In 1761, Franklin was in London, where he regularly attended concerts. One that he attended was by Deleval, a colleague of his in the Royal Academy, who performed on a set of water-tuned wineglasses patterned after Pockridge's instrument. Intrigued, Franklin began working on his invention, intending it to be more convenient to play than wine glasses. He initially called it the "glassychord" but soon settled on the name "armonica" in honor of the musical language of the Italians (after the Italian word for harmony: "armonia"), a fact that he explained in a letter to Italian natural philosopher and electrician Father Giambatista Beccaria (1716–1781).

Franklin worked with London glassblower Charles James in building his armonica. The instrument consisted of variously sized and tuned glass bowls that rotated on a common shaft and was played by touching the spinning bowls with wet fingers. The foot-treadle-operated instrument held 37 glass bowls. The bowl rims were color coded according to note; the C's were red, D's orange, E's yellow, etc.

It took several trials to construct the glass armonica. The glasses were hemispherical with an open neck or socket in the center so they could be fixed on an iron spindle. They were then arranged sequentially on the spindle, the largest at one end and graduating in size to the smallest at the other. The tones depended on the size of the glasses. The spindle was adjusted based on the principle of the common spinning wheel, fixed horizontally in a case, and turned by a wheel attached to its larger end. The performer sat in front of the instrument, and the tones were brought out by applying a wet finger to the exterior of the glasses as they turned around.

The instrument had its world premiere on February 17, 1762, in Spring Gardens, London, when an English musician, Marianne Davies (1743–1818), who had acquired great skill playing it the previous year, played along with her sister, Cecilia Davies, a classical soprano singer who also played the flute and harpsichord. The sisters also performed in front of large audiences in Dublin (1763), other venues in England, and in Europe, where Mozart heard them play. Marianne Davies regularly corresponded with Franklin after her initial concert and expressed her desire to play the armonica once again before her death.

Initially, two instruments were built—one for Franklin, which he later brought back to Philadelphia, and a second for Davies, who toured with it. They were then manufactured in London and sold to the public for 40 guineas each in the late 18th century.

The armonica was quite popular in Germany. Franz Mesmer used it as background music to "mesmerize" his patients. He introduced it to Mozart, who wrote two pieces for it (a solo armonica piece and a larger quintet for armonica, flute, oboe, viola, and cello). Beethoven also composed music for the glass armonica, and many of these musicians' colleagues composed for it as well—approximately 200 pieces for armonica (solo or with other instruments) survive from that era. Franklin himself liked playing Scottish tunes on his instrument for his guests during his eight and a half years in France as the United States' first ambassador between 1776 and 1785.

With the advent of the 19th century, musical preferences changed. Performances moved out of the small, aristocratic halls of Mozart's day into large public concert halls. There, without proper amplification, the armonica could not be heard. Other orchestra instruments such as strings, winds, and brass were all modified to increase their volume, but it was difficult to make the armonica louder. Concert reviews from that era lament the fact that the armonica sounded wonderful but had a problem being heard over other instruments. As such, it gradually lost popularity.

Abhijit Roy

See also Franklin, Benjamin

Further Reading

- Gallo, David A., and Stanley Finger. 2000. "The Power of a Musical Instrument: Franklin, the Mozarts, Mesmer, and the Glass Armonica." *History of Psychology* 3, no. 4: 326.
- Meyer, Vera, and Kathleen J. Allen. 1988. "Benjamin Franklin and the Glass Armonica." *Endeavour* 12, no. 4: 185–88.
- Rossing, Thomas D. 1994. "Acoustics of the Glass Harmonica." *The Journal of the Acoustical Society of America* 95, no. 2: 1106–11.
- Sparks, Jared. 1850. *The Life of Benjamin Franklin*. Boston: Tappan, Whittemore and Mason.

Primary Document: Excerpt of Benjamin Franklin's Letter to Father Giambattista Beccaria Describing the Glass Harmonica (1762)

In 1762, Benjamin Franklin wrote a letter to Father Beccaria, a philosopher at the University of Torino (Italy), about his "armonica." In later years, Franklin said that the glass armonica, with its bell-like tones, was the most satisfying invention of his life. He refused to take a patent out on his improved instrument, believing it belonged to humanity, not himself.

London,
July 13, 1762

Reverend Sir,

I once promised myself the pleasure of seeing you at Turin, but as that is not now likely to happen, being just about returning to my native country, America, I sit down to take leave of you (among others of my European friends that I cannot see) by writing . . .

Perhaps, however, it may be agreeable to you, as you live in a musical country, to have an account of the new instrument lately added here to the great number that charming science was before possessed of: As it is an instrument that seems peculiarly adapted to Italian music, especially that of the soft and plaintive kind, I will endeavour to give you such a description of it, and of the manner of constructing it, that you, or any one of your friends may be enabled to imitate it, if you incline so to do, without being at the expence and trouble of the many experiments I have made in endeavouring to bring it to its present perfection.

You have doubtless heard the sweet tone that is drawn from a drinking-glass, by passing a wet finger round its brim. One Mr. Pockeridge, a gentleman from Ireland, was the first who thought of playing tunes, formed of these tones. He collected a number

of glasses of different sizes, fixed near each other on a table, and tuned them by putting into them water, more or less as each note required. The tones were brought out by passing his finger round their brims. He was unfortunately burnt there, with his instrument, in a fire which consumed the house he lived in. Mr. E. Delaval, a most ingenious member of our Royal Society, made one in imitation of it, with a better choice and form of glasses, which was the first I saw or heard . . .

Being charmed by the sweetness of its tones, and the music he produced from it, I wished only to see the glasses disposed in a more convenient form, and brought together in a narrower compass, so as to admit of a greater number of tunes, and all within reach of hand to a person sitting before the instrument, which I accomplished, after various intermediate trials, and less commodious forms, both of glasses and construction, in the following manner . . .

The advantages of this instrument are, that its tones are incomparably sweet beyond those of any other; that they may be swelled and softened at pleasure by stronger or weaker pressures of the finger, and continued to any length; and that the instrument, being once well tuned, never again wants tuning.

In honour of your musical language, I have borrowed from it the name of the instrument, calling it the Armonica.

With great esteem and respect, I am, Etc.

B. Franklin

Source: Franklin, Benjamin. *Experiments and Observations Made in America at Philadelphia* . . . 4th ed. London: Printed for David Henry; and sold by Francis Newbery, at the corner of St. Paul's Church Yard, 1769, 427–33.

Glover, Elizabeth (d. 1643)

In 1638, Elizabeth Glover set up the first printing press in the Massachusetts Bay Colony's new university—present-day Harvard University.

Glover and her husband, Jose Glover, had sailed from their home in England with their five children and a team

of technicians to the English colonies. They brought a printing press with them to set up there. Glover's husband had originally intended the press to mass-produce religious texts. As a minister, his goal was to spread his religion in the colonies, and printing texts would allow most people, regardless of class, to own copies. But during the voyage to the colonies, Minister Glover passed away.

Upon arriving in Massachusetts, Elizabeth Glover went right to work setting up her printing shop. The first president of Harvard, Henry Dunster, took an interest in her business, and they married three years after she arrived. By that time, the press had already printed the infamous Bay Psalm Book. This book would have been considered crude in the modern day. It had 300 pages of text containing paraphrases of psalms but was loaded with errors. Despite its flaws, 1,700 copies were printed by Glover's business.

Glover passed away two years after she married Henry Dunster, and the business passed to her chief assistant's son, Matthew Daye. Once Matthew died, the business passed to Samuel Green, who printed 1,500 copies of the Bible in a Native American language. This is just one example of the influence that Glover had in what is now the United States. A century later, Ben Franklin, one of the Founding Fathers, used the business she had founded to cut the country's ties with England.

The printing press in the United States not only revolutionized the mass production of books, but it also made reading a common skill of the people rather than one reserved for the upper classes of society. People could read the Declaration of Independence that their country had used to declare its independence from England. Over time, the printed world became a lot bigger—compare the 1,500 copies of the Bible from the mid-1600s to the number of Bibles that now exist in the United States.

Today, most people are literate, and most homes have at least a few books in them. When pastors and priests read passages in church, people can follow along with their own copies of sacred texts. The ability to read and buy affordable books is a circumstance of modern life. This is only a reality in the United States today because of Glover's contribution to the intellectual growth of the 13 colonies.

Camille Michaluk

See also *Vol. 1, Sec. 3: Printing*; *Vol. 3, Sec. 3: e-Book and e-Reader*

Further Reading

Blumenthal, J. 1977. *The Printed Book in America*.

Hanover, NH: The Dartmouth College Library.

Kimber, S. A. 1937. *The Story of an Old Press*. Cambridge, MA: The University Press.

Godfrey, Thomas (1704–1749)

Thomas Godfrey was an American inventor, mathematician, and artisan. He invented the octant, an important navigational instrument, at about the same time that an English mathematician, John Hadley, also created one.

Godfrey was born in 1704, in Bristol, Pennsylvania. He was apprenticed to a glazier as a youth and entered the trade as an adult. He was encouraged to study science and mathematics by James Logan, a botanist and future governor of Pennsylvania. He was also friends with Benjamin Franklin at a young age, but their friendship soured when Franklin rejected marriage to a relative of Godfrey's wife.

Godfrey dedicated himself to the creation of a navigational instrument called an octant. An early version of this instrument was invented by Sir Isaac Newton around 1700, but neither he nor the prominent astronomer Sir Edmond Halley, who saw a detailed description of it, ever published anything about this octant. Like the later devices invented by Godfrey and Hadley, this device consisted of a telescope that is mounted vertically; the horizon is viewed through an angled mirror while the telescope is fixed on a star. An index arm is adjusted until the horizon and star appear to be aligned; the user can then measure the exact angle by looking at the measurement inscribed on the index arm. This let them determine the correct time and thus longitude. The device was called an "octant" because it allowed users to measure angles up to 45 degrees: one-eighth of a circle.

Godfrey became interested in this project by studying astronomical devices and quickly realized the commercial potential of such an invention in an age of sail. He realized that while the octant was technically feasible, creating a portable version was extremely difficult. Godfrey constructed a prototype based on a cruder instrument called a quadrant in 1730, which a Philadelphia captain agreed to take to sea that year. The captain reported excellent results to Godfrey upon his return in mid-1731.

Godfrey demonstrated the octant to Logan, who agreed to present the device to the Royal Society in London. He was delayed a year, however, and in the meantime, the English mathematician John Hadley had come up with a similar device and presented it to the Royal Society. While no one has ever definitively

proven whether Hadley or Godfrey invented the octant first, Hadley announced his first experiments to the Society in 1731, at the same time that Godfrey was finishing his prototype. As vice president of the Royal Society, Hadley was prominent enough to receive a patent without contest in 1734.

Godfrey protested and noted that Hadley's nephew had been present at an early demonstration. The Royal Society did not relent but did eventually grant Godfrey a cash reward for his work. While Hadley called his device a "reflecting quadrant," today the common term is "octant," the name that Godfrey gave to it. In 1749, Godfrey died; in the same year, Hadley's patent expired, and the octant entered widespread use around the world.

James L. Erwin

See also Franklin, Benjamin

Further Reading

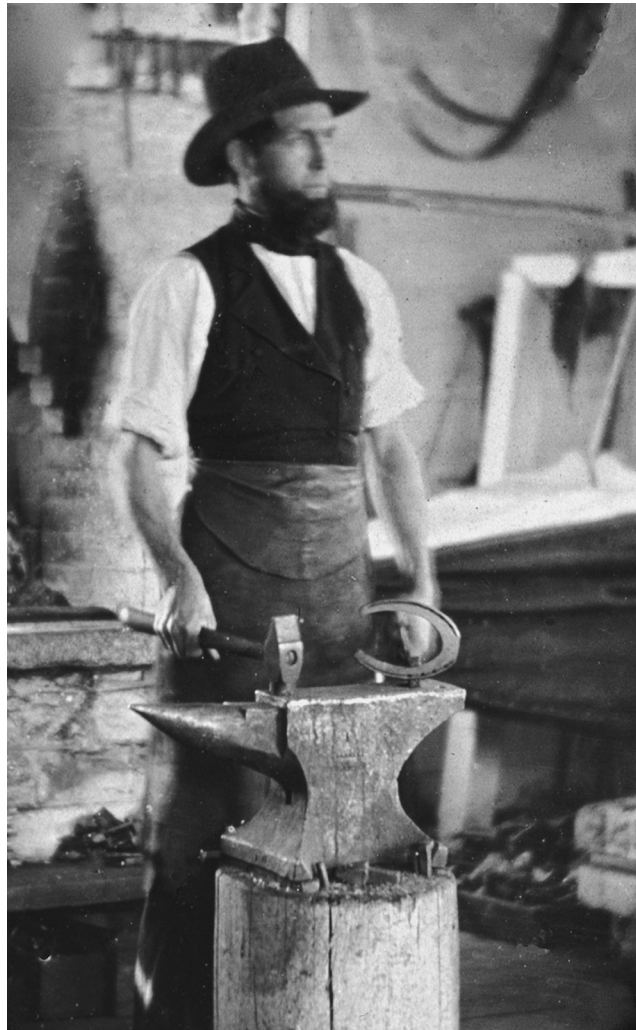
Bedini, Silvio A. 1984. *At the Sign of the Compass and Quadrant: The Life and Times of Anthony Lamb*. Philadelphia: The American Philosophical Society.

Franklin, Benjamin. 1996. *The Autobiography of Benjamin Franklin*. Mineola, NY: Dover.

Home Weaving. See Loom

Iron- and Silversmithing

Iron- and silversmithing were first introduced to North America in the late 17th century. An ironsmith or silversmith is a craftsman who creates items out of that specific element. Some examples of silversmithing include the creation of dishes, vases, and silverware. Silversmiths cut and shape items from silver by heating up the metal, which allows easy shaping with a hammer or bending tools. Silversmithing was especially popular in the late 17th century, because, unlike the element gold, it has less value but is very similar in strength and purpose. Iron- and silversmithing was also in high demand during other periods, such as that of World War II. Not only was smithing good for



This daguerreotype of a blacksmith in his workshop ca. 1855 highlights his most important tools and his most frequent product: the horseshoe. (Library of Congress)

making household items, but it also was used to create weapons.

Ironsmithing began with blacksmithing. The process consists of heating the metal until it melts and then later cooling it after the item is made. Although very useful in many ways, ironsmithing was not always seen as a good thing; some early villages banned the process, saying it was evil because of its ability to create weapons. Blacksmiths also experimented with different types of metals to see if any were as resistant and strong as iron, leading them to discover other ways of dealing with iron and other metals. The process of shaping metal with a hammer is called "forging." In the smithing process, iron is heated

and its color changes with the temperature—from red to orange to yellow and finally, white. To see the color changes, blacksmiths work in low light. The finishing processes for the items made in iron- and silversmithing consist of smoothing, sharpening, polishing, and brightening. Blacksmiths have always been seen as artists for their ability to transform metal into useful items.

Today, silver- and ironsmithing are still used. Smithing is an art that can produce household items such as coffeepots and silverware for daily use. A new interest in smithing arose in the later 20th and early 21st century, creating an association of blacksmiths of almost 4,000 members. Old West theme parks such as Knott's Berry Farm in Buena Park, CA, may have small smithing stores where tourists can have items created. The blacksmiths in these parks also make horseshoes for the animals in the theme park. Smithing has come a long way, from creating weapons of destruction to household items to horseshoes.

Belen Cardenas

See also *Vol. 1, Sec. 3: Coal-Mining Technologies; Gold-Mining Technologies*

Further Reading

- Ensko, Stephen. 2012. *American Silversmiths and Their Marks: The Definitive Edition*. New York: Courier.
- Montgums, Olive. 2017. *Silversmithing: A Beginner's Guide to Designs, Technologies, Techniques and Methods for Jewelry Making*. Amazon Digital Services.
- Sloan, Eric. 2005. *Once Upon a Time: The Way America Was*. New York: Dover.

Kentucky Long Rifle

The American long rifle, sometimes referred to as the Kentucky or Pennsylvania long rifle, was one of the first rifles to be mass-produced and used regularly for both hunting and war.

The Kentucky long rifle owes its origins to gunsmiths and craftsmen of Austrian and German descent. Up until the 15th century, muzzle-loaded firearms

used a barrel with a smooth bore, which required the projectile to be slightly smaller than the bore. This caused a loss of muzzle velocity and seriously degraded accuracy.

Sometime during the 15th century, Gaspard Koller of Vienna created a firearm with straight, parallel grooves inside the length of the barrel. In 1520, Augustus Kotter of Nuremberg is believed to have turned the grooves into a spiral along the barrel axis, thereby imparting spin to the projectile. Despite these achievements, smoothbore muskets were used by infantries for another 300 years because they did not suffer as much from the complication of fouling caused by black powder, which was difficult to clean from the grooves.

As more Europeans settled in the New World, German hunters and gunsmiths settled throughout Appalachia, notably Jacob Dickert, Robert Baker, and Martin Meylin of Pennsylvania. These craftsmen manufactured copies of the German *Jaeger* rifle with some important modifications, such as a longer barrel. European rifles had shorter barrels (30 inches or less) and used higher-caliber ammunition, which required more powder and lead. This was undesirable for hunters on foot in the American woodlands. By lengthening the barrel to 42 to 46 inches, the gun makers were able to use lower-caliber ammunition and less powder while improving the firearm's performance. After the Revolutionary War, trappers and explorers crossed the Appalachian Mountains westward with their long rifles and were greeted by the Cumberland Plateau and Kentucky's diverse wildlife.

The long rifle is particularly known for its pleasing aesthetics. Its long and gracefully carved stock was often made of maple, and many rifles had carved and decorated stocks that echoed trends in fine American furniture. While early versions of the rifle were quite plain, by the late 1770s, every surface that could be decorated on the rifle often was, from the wooden stocks to the metal flintlocks.

The rifle made its military debut in the French and Indian War or Seven Years' War (1754–1763). The long rifle had played a pivotal role in turning the tide of the American Revolution in favor of the colonial rebels. In December 1814, General Andrew Jackson assembled 4,500 troops that included 968 members of the Kentucky militia to fight the British in the battle of

New Orleans. The “Kentucky rifle” became legend in a song commemorating this event.

However innovative the Kentucky rifle was, it remained problematic for soldiers until the invention of the minié ball, a rifle bullet that proved considerably easier to load and more stable in its flight than previous rifle balls. By the 20th century, the Kentucky long rifle had essentially disappeared from the American gun landscape except for in a few pockets of the Appalachian Mountains. In the late 20th and early 21st century, the rifle has enjoyed a revival, with boutique gunsmiths crafting modern interpretations of the centuries-old weapon.

Peg A. Lamphier

See also *Vol. 1, Sec. 3: Military Technology (Civil War); Repeating Rifle*

Further Reading

Wallace, Gusler. 2003. *Three Centuries of Tradition: The Renaissance of Custom Sporting Arms in America*. Minneapolis: Minneapolis Institute of Arts.

Lightning Rod

Benjamin Franklin (1706–1790) invented the lightning rod in 1752. This invention resulted from Franklin’s study of electricity and his belief that his rod conductors could save humans and buildings from the destructive force of lightning strikes. A lightning rod is a metal rod attached to the top of a structure and connected to the ground through a wire. The electric charge from lightning strikes the rod, and the charge is conducted harmlessly into the ground.

Franklin had a lengthy résumé in an age when most people could only list farming or homemaking as their lifelong career path. During the course of his life, Franklin was an author, civic activist, community leader, diplomat, educator, humorist, inventor, philosopher, printer, politician and political theorist, postmaster, scientist, statesman, and, incidentally, one of the Founding Fathers of the United States. Four centuries later, he might also have included terms that were nonexistent during his lifetime in the 18th century, such as technological innovator. Along with that, another would probably have delighted him: storm

chaser. Once Franklin had an understanding of the behavior of electricity, which he is said to have found firsthand in a thunderstorm, he set about trying to protect buildings from the destructive forces of lightning.

Franklin became fascinated with the study of electricity, closely following the electrical experiments of other scientists. In 1746, he accidentally shocked himself during one experiment in his home laboratory. As soon as he recovered and while still experiencing numbness in his arms, he wrote about his experience and the effects of electricity on his body. Franklin continued his experiments, corresponding with other scientists. Often he had to invent new terms for elements of the little-known field of electricity, such as “battery,” “charge,” “conductor,” and “positive” and “negative” as descriptors of the charge—terms still in use today.

By 1749, Franklin became convinced that there were similarities between electricity and lightning. Both had a crooked direction, a crackling noise, and the same color of light. While some other scientists believed the same, Franklin was determined to find a way of proving it. He also began thinking about ways to protect people and buildings from the destructive effects of lightning—ergo, the lightning rod.

In June 1752, Franklin grew tired of waiting for other ways to test his theory, so, allegedly venturing out into a thunderstorm that hit Philadelphia, the legend of Franklin’s “kite-and-key” experiment was born. With his 21-year-old son William as the only witness, Franklin was said to have tied a metal key to a kite using only silk ribbon on his knuckles to protect his hand. Though some historians claim that Franklin did not go out into the worst part of the storm or that he withdrew at the first sign of danger, the story continues to resonate in popular history. Some writers assert that the kite-and-key episode was a myth propagated by Franklin himself 15 years later—one that had repercussions for the ultimate success of the American Revolution. Their theory is that the British feared that Franklin had created an electric superweapon.

Franklin’s initial thoughts about electricity focused on the ways in which the unseen force could be channeled to save humans and structures from lightning strikes. He theorized that pointed rods could draw the electrical fire from the clouds, thus preventing chaos and destruction. He developed the metal rods and began

marketing them to colonial Americans in the mid-18th century. Franklin was convincing enough that lightning rods could soon be found protecting colonial America's homes and buildings such as the Maryland State House. Its lightning rod was constructed and grounded according to Franklin's own direct specifications, and in almost 250 years of use, there has only been one recorded instance of lightning damage to the structure.

Nancy Hendricks

See also Franklin, Benjamin

Further Reading

Dray, Philip. 2005. *Stealing God's Thunder: Benjamin Franklin's Lightning Rod and the Invention of America*. New York: Random House.

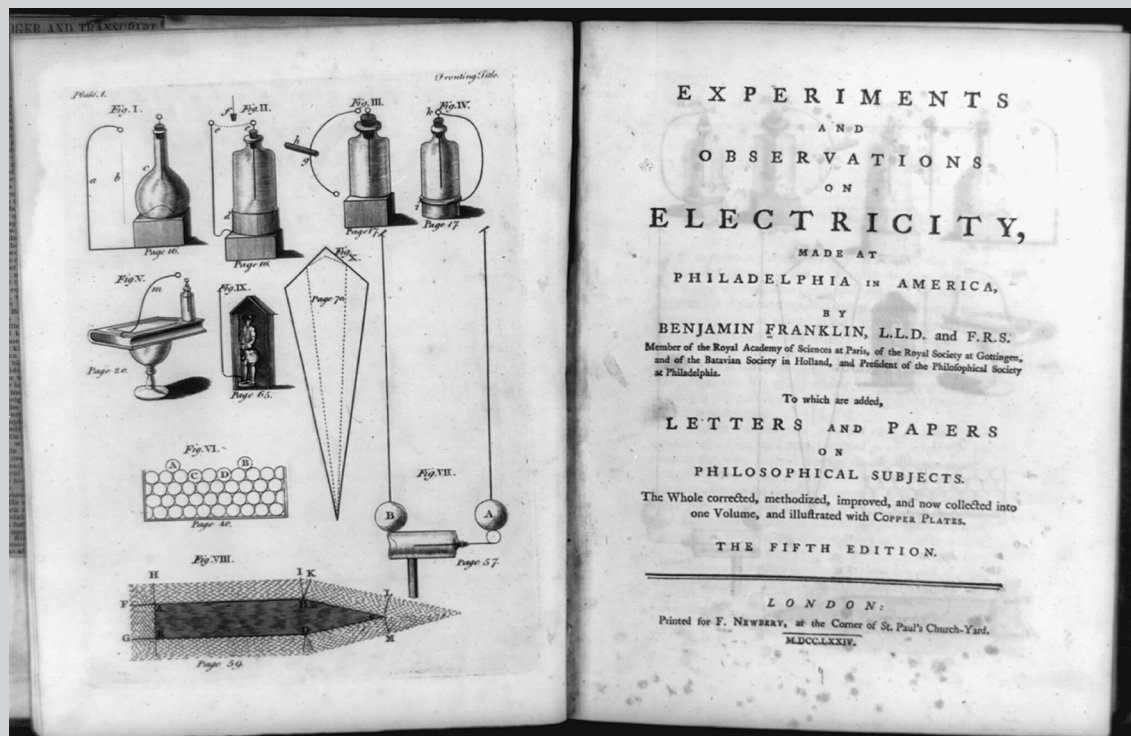
Tucker, Tom. 2003. *Bolt of Fate: Benjamin Franklin and His Electric Kite Hoax*. New York: Public Affairs.

Primary Document: Frontispiece and Title Page of Benjamin Franklin's *Experiments and Observations on Electricity* (1774)

Benjamin Franklin's *Experiments and Observations on Electricity* was first published in 1751 as a 90-page pamphlet. The pamphlet comprised a collection of letters written by Franklin to Peter Collinson and other scientists at the Royal Society in London regarding his experiments with electricity. Because of public interest in Franklin's ideas and observations, the Society collected and published the letter. The first edition was

followed by various other editions and supplements until the 1769 publication of a hardcover volume of almost 500 pages that eventually went through several later editions and was translated into German, French, Italian, and Latin. Reproduced here is the frontispiece and title page of the 1774 edition.

Source: Library of Congress.



Loom

In colonial America, England prohibited progress in weaving technology, prompting the birth of a home weaving moment. Looms became technological symbols of rebellion, disseminating mechanical thinking across social and economic classes, inspiring regional innovation, and creating physical emblems of self-sufficiency—home-woven textiles called “homespun.”

A loom enables a skilled operator to transform thread and yarn into fabric. Until the invention of mechanized power looms in 1790, all fabric for clothing, sheets, blankets, cloth bags, and even ship sails was woven by hand.

Beginning in the Middle Ages, woolen cloth production was a leading English industry. The powerful Weaver’s Guild controlled who could learn the trade and access loom technology. By the 17th century, a growing home-centered weaving movement threatened the Guild’s control, and it responded with suppressive regulation. Protestant weaving families felt persecuted and became early immigrants to the New England colonies. Some secretly brought their precious looms with them.

The looms that colonists brought to the New World were 11th-century technology. Four-post English box looms produced fabric narrower than three feet, but they offered options for intricate patterns. Cantilevered looms made bed-width fabrics but with less pattern capability.

A loom produces cloth by holding threads at right angles to each other as they are interwoven. “Warp” threads run the length of the fabric and provide its foundation. These long threads must be set up precisely on the loom for the cloth to be straight, square, and evenly patterned.

The threads running perpendicular to the warp are called “weft.” Weft thread is spooled out from a “shuttle” as it is alternately woven over and under the warp threads.

The English box loom had additional wooden bars that could change which warp threads were being woven, thereby creating patterns. After each pass of the shuttle through the warp, a wooden or metal bar tapped the weft threads tightly into place to make a smooth, solid fabric.

An English box loom’s wooden frame stood up to seven feet tall and covered an area similar to a four-poster bed. Though it could be taken down and transported, a loom was a large, complex machine. A family might devote an entire room or loft to a loom and textile production.

Initially, colonists were supplied with or purchased all of their clothing and textiles as England maintained its monopoly on woven woolen goods.

New England winters, however, were colder than expected, supply ships were fewer, and income for purchasing clothing was lower. Supplemental production of wool yarn became an important household endeavor. By 1656, Massachusetts Bay required all women and children to spin and process wool when not busy with other tasks. Processing flax plants into linen also became a practical necessity. Flax grew naturally in North America, and by 1640, Jamestown colonists were required to grow and process an annual minimum amount of flax or be fined.

While England and Holland discouraged or prohibited colonial textile production, a large number of early immigrants were skilled weavers. The combination of need and knowledge built a home-based movement for creating woven textiles for personal use. Most villages had a man, woman, or family that provided weaving services for fee or barter. Looms could not be imported, but weavers worked with wood craftsmen to replicate the few looms that had been smuggled into the colonies. Loom technology, which was closely controlled in Europe, was openly shared.

Colonists did not physically change loom technology, but they experimented with fibers and pattern. Scotch-Irish immigrants in New Hampshire were linen weavers. Wool shortages inspired combinations of linen warp with wool weft. The mixed-fiber cloth—called “linsey-woolsey”—was lightweight and strong like linen, yet warm and fire resistant like wool. Dutch-speaking German immigrants in Pennsylvania also had expertise in weaving linen. They developed a pattern technique called “American double-weave” or “double-face.”

Double-weave used the same looms but involved two layers of warp threads—one of colored wool and one of white wool or linen. This meant that two layers of fabric were woven simultaneously, one above the

other, and interwoven. This technique was typically used to produce blue-and-white geometric-patterned bed coverings. The blanket-like textiles had a white pattern with a blue background on one side and a blue pattern with a white background on the reverse. The light and dark sides inspired the name “summer-winter.”

Large Southern plantations employed experienced Irish linen producers to train African slaves in spinning and weaving. The rough linen they produced, referred to as “Virginia cloth,” was primarily used for slave clothing.

Through periods of war and economic recession, home-produced textiles provided a valuable alternative to expensive imports and became a patriotic symbol to unify colonists. The English regarded “homespun” both as a lower-class nuisance and a threat.

The English Wool Act (1699) tried to stop colonial manufacturing by prohibiting the sale of wool products between colonies or for export. The 1764 Sugar Act taxed imported fabrics and silk, convincing even wealthy colonists to embrace homespun clothing as a protest against English taxation. Large groups of women spinning in public or home weavers producing fabric were peaceful demonstrations against English rule.

During the Revolutionary War, Martha Washington used her plantation weavers to make wool cloth for soldiers’ clothing. She even recycled red silk yarn from George’s old socks to make a red-striped homespun fabric for herself. Throughout the colonies, the home weavers contributed to the war effort by creating wool coats for soldiers.

Following independence, the new country struggled financially, and government leaders discouraged

consumption of imported products. Producing homespun clothing again demonstrated patriotic nationalism. More looms and spinning wheels were produced, but they were old technology. American invention first impacted the production of traditional tools like wool cards.

The diary of Martha Ballard (1735–1812) provides rare documentation of home-based textile production and the economic benefit of a home loom. For a generation, industrialization did not eliminate the home weaving movement. Looms and spinning wheels continued to be passed down through families as long as the American frontier was being settled and homespun had value in a barter economy.

Keri Dearborn

See also Spinning Wheel; *Vol. 1, Sec. 2*: Ballard, Martha; Cotton Gin; Cotton Sewing Thread; Greene, Catharine Littlefield

Further Reading

Cole, Arthur Harrison. 1926. *The American Wool Manufacture*. Cambridge, MA: Harvard University Press. <https://archive.org/stream/americanwoolmanu029958mbp#page/n57/mode/2up>, accessed August 22, 2018.

Earle, Alice Morse. 1974. *Home Life in Colonial Days*. Stockbridge, MA: The Berkshire Travelers Press.

Parslow, Virginia D. 1949. *Weaving and Dyeing Processes in Early New York*. Cooperstown, NY: The Farmer’s Museum. http://www.cs.arizona.edu/patterns/weaving/monographs/pvd_ny.pdf accessed August 22, 2018.

Primary Document: Excerpts from the Diary of Martha Ballard Describing Home Weaving (1787)

Colonial Americans experienced a shift in the gendered work of spinning and weaving. Previous to the decades surrounding the American Revolution, home weaving was seen as men’s work, and also as a full-time occupation. New home looms transformed the work of weaving into women’s work that could be

done alongside other domestic tasks. The following are excerpts from Martha Ballard’s diary, suggesting the kinds of work involved in home weaving and the way that work was integrated into domestic life. The entries also illustrate how weaving was a collaborative labor and not one undertaken by women alone.

May 24, 1787

Clear. we warpt a webb of 42 yds Linnin. I went to mr Williams^s, his wife is better. mrs Pollard here at Evinng. mr Hodges Came there Last Evinⁿ. Revd mr Foster here afterⁿ. mr Ballard been fixing the loome.

May 25, 1787

rainy fore noon. Dorkis Pollard here to warp a piece. mr Ballard fixing the loom. Hannah Coll Sett the webb to work. mrs Voce here, says mrs Pattin is very unwell. Jonathan Bro^t home 9 lb of hard Bread which Cost /5 pr lb.

May 26 1787

Clear. I planted pepers, anis & coriander. mr Rich from the westward workt here, Jonⁿ afterⁿ. Polly Bisbee here. I combd 7-1/2 lb of flax for myself & [4] 1/2 for Cyrus.

May 28, 1787

Clear. I am more Comfortable than I was yesterday. mr Ballard Bro^t our Kittle from Savages. mr Edy asistided him. we Boild a Linning warp, 55 Skeins. the girls gon to mr Craggs. mr Howard Left here y^smorn.

June 2, 1787

Clear. I quilld 7 Skeins of yarn. Cyrus Bot 2 lb of Butter. mr Ballard Bro^t home 14 lb Cod fish. Son Town Slep^t here last night. I went to mr Westons, Bot a XXXVI Slay. Son Town here.

Source: Ballard, Martha. Diary entries, May and June 1787. *The Diary of Martha Ballard, 1785–1812*. Maine State Library. <http://dohistory.org/diary/themes/textile/>, accessed August 22, 2018.

Lucas, Eliza (1722–1793)

Eliza Lucas was born in the British West Indian island colony of Antigua. Best known as an innovator in the field of agronomy and as the mother of two influential men in American revolutionary history, Lucas entered the world in a time and place of great change in terms of both the spread of empire and the expansion of agricultural and economic pursuits in recently settled parts of the Americas and the Caribbean. As a botanist and follower of Enlightenment principles in both her scientific and personal endeavors, Lucas helped shape the economic and political history of America.

Lucas spent her youngest years immersed in the world of agriculture on the sugar plantation owned by her father Captain George Lucas. In 1732, Captain Lucas sent his daughter to England to be educated, selecting courses in mathematics, bookkeeping, geography, history, literature, and her greatest interest, botany. When she completed her formal education in 1738, she returned not to Antigua but to her father's South Carolina plantation, one of three he owned in that colony. Upon Captain Lucas's recall to Antigua for military service, the 16-year-old Lucas found

herself in charge of all three plantations as well as the care of her ailing mother and younger sister.

By educating her well and nurturing her natural talents and intellect, Captain Lucas had prepared his daughter to brilliantly manage plantation affairs. Her natural affinity for botany and the determination to make the plantation prosper encouraged her to experiment with various crops, the most important one being indigo. Early attempts at indigo culture had been unsuccessful, and rice was the most important export crop for South Carolina. By the time Lucas began her experiments, rice culture had become less profitable, leaving growers to search for an alternative staple crop, and indigo looked promising.

Many women of Lucas's social class studied botany, but few followed it with her purpose or intensity. She kept detailed records of her experiments in the improvement of indigo culture from planting to processing. When she married planter and attorney Charles Pinckney in 1744, she cemented her relationship with a man who knew and appreciated her aptitude and who became a cheerleader for her accomplishments. Pinckney spread information regarding his wife's experiments and promoted indigo production to a broad spectrum of South Carolina agriculturists.

Lucas's methods regarding the growth and processing of indigo helped to produce a better-quality product and expand production, while her influential husband secured a royal subsidy on South Carolina indigo. As a result, between 1744 and 1774, South Carolina's production of finished indigo grew from almost zero to over a million pounds. While this represents Lucas's main accomplishment, she also worked to improve other crops and conducted research in other agronomy-related methods that are commonplace today, such as intensive farming, crop rotation, and grafting.

Her two sons, Charles Cotesworth and Thomas, were prominent in the history of revolutionary America and the Early Republic; her daughter, Harriott, is best known for the preservation of her mother's letterbooks, a three-volume set that extends from 1739 to

1762 and provides extensive information regarding Lucas's life and interests.

Eliza Lucas Pinckney died in Philadelphia in 1793, a victim of breast cancer.

Lee Smith

See also *Vol. 1, Sec. 2: Three-Piece Iron Plow; Vol. 3, Sec. 2: Sustainable Agriculture*

Further Reading

Ravenel, Harriott Horry. 1896. *Eliza Pinckney*. New York: Scribner's.

Schulz, Constance B. 1998. "Eliza Lucas Pinckney." In *Portraits of American Women: From Settlement to the Present*, edited by G. J. Barker Benfield and Catherine Clinton, 56–64. New York: Oxford University Press.

Primary Document: Letter of Eliza Lucas to Her Father (1741)

Eliza Lucas Pinckney's letterbook contains letters written between 1739 and 1762. The collection is considered one of the finest primary document sources of plantation and family life written by a woman of the time. The following is a letter Lucas wrote to her father in 1741 when she was 19 years old, discussing a variety of topics, including farming and planting. Note that for Lucas, domestic, family, and farming details are intertwined.

June 4, 1741

Never were letters more welcome than yours of Feb. 19th and 20th and March the 15th and 21st, which came almost together. It was near 6 months since we had the pleasure of a line from you. Our fears increased apace and we dreaded some fatal accident befallen, but hearing of your recovery from a dangerous fitt of Illness has more than equaled, great as it was, our former Anxiety. Nor shall we ever think ourselves sufficiently thankful to Almighty God for the continuance of so great a blessing. I sympathize most sincerely with the Inhabitation of Antigua in so great a Calamity as the scarcity of provisions and the want of the Necessarys of life to the poorer sort. We shall send all we can get of all sorts of provisions particularly what you write for. I wrote

this day to Starrat for a barrel [of] butter. We expect the boat dayly from Garden Hill [plantation] when I shall be able to give you an account of affairs there. The Cotton, Guiney corn, and most of the Ginger planted here was cutt off by a frost I wrote you in [a] former letter we had a fine Crop of Indigo Seed upon the frost took it before it was dry. I picked out the best of it and had it planted but there is not more than a hundred bushes of is come up—which proves the more unlucky as you have sent a man to make it. I make no doubt Indigo will prove a very valuable Commodity in time if we could have the seed from the west Indias [in] time enough to plant the latter end of March, that the seed might be dry enough to gather before our frost. I am sorry we lost this season. We can do nothing towards it now but make the works ready for next year. The Lucern is yet but dwindling, but Mr. Hunt tells me 'tis always so here the first year. The death of my Grand-mamma was, as you imagine, very shocking and grievous to my Mama, but I hope the considerations of the misery's that attend so advanced an age will help time to wear it off. I am very much obliged to you for the present you were so good to send me of the fifty pound bill of Exchange which I duely received. We hear Carthagene is taken. Mr. Wallis is

dead. Capt. Norberry was lately killed in a duel by Capt. Dobrusee, whose life was dispaired of by the wounds he received. He is much blamed for querrelling with such a brawling man as Norberry who was disregarded by every body. Norberry has left a wife and 3 or 4 children in very bad circumstances to

lament his rashness. Mama tenders you her affections and Polly joyns in duty with My Dr. Papa Y[our]. m[ost]. ob[edien]t. and ever D[evoted] D[aughter] E. Lucas

Source: Ravenel, Harriott Horry. 1896. *Eliza Pinckney*. New York: Charles Scribner's Sons, 12–13.

Masters, Sybilla (c. 1675–1720)

Sybilla Righton Masters was an American inventor from Pennsylvania. She was the first American colonist to receive an English patent, and she ultimately secured two: one for a corn grinding machine and another for a weaving technique initially designed for palmetto leaves.

Sybilla Masters was born to William Righton, a merchant and mariner, and Sarah Murrell. Her exact birth date and place of birth are unknown, but her Quaker father immigrated from Bermuda to the colony of West Jersey in 1687. Sometime between 1693 and 1696, Sybilla married Thomas Masters, a successful merchant and landowner. The couple would eventually have four children. Thomas was a prominent member of Philadelphia's Quaker community, serving in a number of political positions, including alderman of Philadelphia, mayor in 1707 and 1708, and provincial councilor, 1720–1723.

In 1712, Masters traveled to London to secure patents for her inventions, since Pennsylvania was not yet granting its own. Masters had to apply using her husband's name, since women were unable to receive patents under English law. She did, however, receive credit in the application's description as the inventor. King George III eventually granted her request on November 25, 1715. Her corn milling device used a stamping process to crush corn, an improvement over the previous methods, which used heavy millstones to grind the grain. Masters's device was inspired by her observations of Native American women's work with maize. Her machine was powered by horse or water and consisted of a series of heavy pestles that descended through a long wooden cylinder into a

continuous row of mortars, which held the corn kernels. The crushed product then descended into a row of basins for drying. The Masterses called the resulting meal "Tuscarora Rice"—today known as "hominy" or "grits." The couple was hoping to export their product to England, but it was never popular there.

During Sybilla's absence, Thomas Masters acquired the Governor's Mill, a mill built for William Penn in 1701. He used it to produce large quantities of the meal, which he promoted as a cure for consumption. Sales were disappointing, however, and Masters soon converted the mill to other purposes.

Sybilla Masters acquired the second patent in London, on February 18, 1716, for a method of weaving and staining palmetto and straw leaves. While in London, waiting for news on her patent applications, Masters opened her own shop, the West India Hat and Bonnet. Having been granted a monopoly on the importation of the palmetto leaf from the West Indies, she used her new process to weave a variety of goods, including adornments for bonnets, baskets, mats, furniture coverings, and childbed baskets. Masters returned to Philadelphia in 1716. Her husband petitioned the provincial council to record and publish her patents in Pennsylvania, which it did on July 15, 1717. Masters died in 1720, probably in Philadelphia.

Kathleen Barker

See also Colden, Jane; Glover, Elizabeth; Lucas, Eliza

Further Reading

Hertzog, Kate. 2007. *More Than Petticoats: Remarkable Pennsylvania Women*. Guilford, CT: TwoDot.

Mather, Cotton (1663–1728)

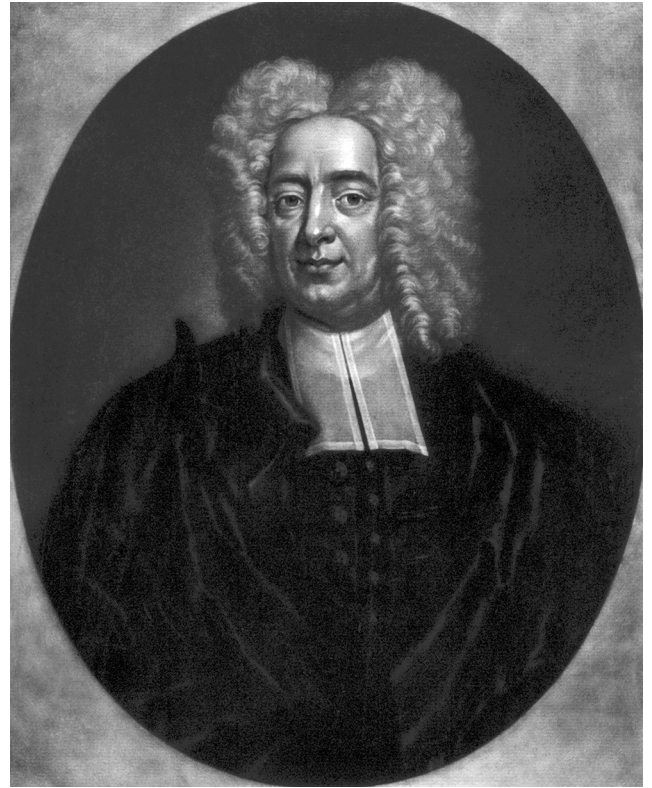
Though Cotton Mather is primarily known for his role in the infamous Salem witchcraft trials, he was also a well-known and highly regarded scientist. His international fame is witnessed by the conferring of an honorary doctorate on him in 1710 by the University of Glasgow.

Mather was born in Boston, Massachusetts Bay Colony. He had illustrious ancestors on both sides of his family. His mother was named Maria Cotton, and his father was the famous Increase Mather. His maternal grandfather was John Cotton, and Richard Mather was his paternal grandfather. Each of these men was a famous Puritan minister.

Mather was well educated. Before attending Harvard College, he studied at Boston Latin School and was entered into its Hall of Fame. Mather was a Harvard College graduate, earning an AB in 1678 and an AM in 1681. Like his father, he became a Puritan leader in New England as a minister and an author of books and pamphlets. After completing his undergraduate and graduate studies, he became an assistant pastor at Boston's original North Church, under his father's leadership. Mather succeeded his father as pastor in 1685. Despite his heavy responsibilities there, he managed to author over 450 books and pamphlets. Mather hoped to become president of Harvard College, but for various reasons, including his support of the Salem witch trials, he was denied the position.

Mather had a lifelong interest in science. He was a strong supporter of inoculation as a means for preventing disease. He had learned of the practice in 1706 from one of his father's slaves and, after educating himself on the possibilities of inoculation, pressed for its more widespread use in the colonies. Significant cultural forces, including Benjamin Franklin's brother James, opposed inoculation. The ensuing controversy not only embroiled the New England medical community but the Puritan hierarchy as well. Many Puritan leaders argued that smallpox was part of God's plan and that suffering should not be prevented. Mather continued to argue for the efficacy of inoculation until his death.

He also experimented with plant hybridization. His theory is presented in his work *Curiosa Americana* (1712, 1714), and it was the basis of Carl Linnaeus's



While Cotton Mather is primarily famous for the part he played in the Salem Witch trials, he was also a great supporter of smallpox vaccinations. He learned of vaccinations from his slave Onesimus, who had been inoculated in Africa. (Library of Congress)

system of botanical classification. In 1713, the Royal Society of London honored Mather, naming him a fellow and making him only the eighth American to receive that title.

Mather was instrumental in establishing the mood and manners for third-generation Puritans. He sought to reconcile Calvinistic beliefs with modern science. In his works, he moved toward what he thought of as rational religion. Perhaps the most influential of his writing was the *Magnalia Christi Americana* (1702) in seven volumes. These books contain biographical and historical information supporting his teachings on rational Christianity.

At the same time, Mather was also a major influence on American science. His work on the hybridization of corn was significant in the later development of Linnaeus's botanical typology. His own work was influenced by that of Robert Boyle, especially *The Usefulness of Experimental Natural Philosophy*.

Interestingly this work influenced not only Mather's scientific ideas but also his religious teachings and observations.

Despite his outstanding efforts in science and rational religion, Mather is remembered mainly for his role in the Salem witch trials. Mather's 1689 work *Memorable Providences* is often cited as the cause of the 1792 trials. It is an account of the assumed afflictions of children in a Boston family. The alleged culprit was an Irish servant, a Catholic named Goody Glover. She was accused and convicted of being a witch and executed. He vigorously defended the legitimacy of the trials and never issued any denials or statements of doubts concerning them.

Robert Calef, a contemporary of Mather, stated that this work was the cause of the Salem witch trials, noting that Mather was very involved in them—more so than any other minister in America. He “Intrigue[d] with that Child,” a child he took into his home, to work against the accused women. His printed accounts, said Calef, stirred up the fires and threatened the stability of the area as well as provoking the execution of dozens of men and women.

Not only did Mather not recant his support of the trials, he continued to defend them long after most supporters had recanted and apologized for their actions. Indeed, he wrote *Wonders of the Invisible World* (1693) in his defense of the trials. It supported Lt. Governor Stoughton's role in the trials and offered his views on the trials themselves. In fact, he became stronger in his defense of the trials as years went on and compared the ones in America with those in Europe. He also included several of his sermons defending his views on the types of evidence that could be used, including spectral evidence—the information that witnesses garnered from ghosts. In the end, Mather's complicity in the witch trials obscured both his religious and scientific achievements. He died in 1728.

Frank Salomone

See also Smallpox Inoculation

Further Reading

Boyle, Robert. 1664–1671. *The Usefulness of Experimental Natural Philosophy*. Oxford: Printed by H. Hall for R. Davis.

Calef, Robert. 1972 [1700]. *More Wonders of the Invisible World*. New York: York Mail-Print.

Hill, Frances. 1997. *A Delusion of Satan*. Old Saybrook, CT: Tantor eBooks.

Mather, Cotton. 1693. *The Wonders of the Invisible World*. London: For John Dunton.

Mather, Cotton. 1911. *Diary of Cotton Mather, 1681–[1724]*. https://archive.org/details/cu3192409220_2500, accessed August 22, 2018.

Mather, Cotton. 2009. *Magnalia Christi Americana*. Charleston, SC: BiblioBazaar.

Miller, Perry. 1981. *The New England Mind, from Colony to Province*. Cambridge, MA: The Belknap Press of Harvard University Press.

Rosenthal, Bernard. 1997. *Salem Story*. Cambridge: Cambridge University Press.

Natural History

Natural history is the observation, description, and collection of quantitative data concerning natural systems, living species, and nonliving elements, with an emphasis on relationships. In the United States, the natural history movement of the mid-18th to the 19th century disseminated scientific information and ideas to an economically and socially diverse population; popular science was no longer an exclusive privilege of the upper class. This was not an organized movement but rather the timely intersection of visionary individuals like Benjamin Franklin (1706–1790), the Quaker religion, the free flow of ideas in a newly independent republic, and the ascension of natural history devotees like Thomas Jefferson (1743–1826) to governmental power.

In the 18th century, the term “scientist” did not yet exist. Scientific pursuit was not considered an occupation. In 1723, second-year students at Harvard College (now Harvard University) studied a few weeks of “natural philosophy”—philosophical explanations for natural phenomena—not data-based science. While modern science divides natural history into specific fields (biology, botany, geology, paleontology, climatology, astronomy, physics, etc.), natural history in the 18th century was all-inclusive. Inquiring individuals made observations and asked: What is this? Why does it behave this

way? How is it different or similar? And, how are all of these pieces of the natural world interconnected?

Natural history study began in Europe, where a few individuals, mostly wealthy gentlemen, had the opportunity to pursue science as an avocation. The Royal Academy (1660) in England and the French Academy of Sciences (1666) were membership organizations founded to support scientific inquiry and peer review of experiments and hypotheses.

Early English colonists spent most of their time working to obtain food, clothing, and shelter; pure scientific pursuit was limited to upper-class or wealthy individuals, such as botanist Jane Colden (1724–1766). For inquiring individuals, scientific investigation occurred within the course of daily work. Ironworker Joseph Jencks (1599–c. 1682) experimented with physics as he generated hydropower for his iron foundry. Eliza Lucas Pinckney (1722–1793) conducted horticultural studies in the operation of her plantation.

Benjamin Franklin incorporated his broad scientific interests into his printing business by publishing science-related articles in his *Pennsylvania Gazette* newspaper. A young Franklin had access, through wealthy friends, to rare and expensive scientific books. By publishing ideas from these sources in his various publications, Franklin disseminated privileged information to the general public. He initiated Americans into the sciences and became a catalyst advancing the natural history movement.

Franklin encouraged readers to document observations of natural phenomena and to collect data on weather. He inspired scientific inquiry while cultivating a future audience for his almanacs. In 1743, Franklin and other like-minded individuals established the American Philosophical Society (APS) in Philadelphia to investigate natural history and promote innovation. Franklin's first experiments with electricity were conducted on loaned APS equipment. As the largest city in the British colonies, Philadelphia was influential, and its Quaker roots created a fertile birthplace for the rise of science in North America.

The Quaker religion emphasizes individual actions over biblical scripture. Seeking truth through inquiry shapes the Quaker worldview and is conceptually similar to the scientific method. Quaker society offered the greatest gender parity of the time and nurtured

inventors of both genders, such as Hannah Wilkinson Slater (1775–1812) and Daniel Wilkinson (1771–1852). Franklin and the Quakers believed that understanding natural phenomena could provide solutions to everyday problems.

As a founder of the College of Philadelphia (now the University of Pennsylvania), Franklin approved the first natural history courses on plants and animals in the colonies (1756). In 1786, the Quaker-founded College of Rhode Island (now Brown University) became the first to designate a natural history professor: Benjamin Waterhouse (1754–1846). Waterhouse later cofounded Harvard Medical School and become the first physician to test the smallpox vaccine in the United States.

From Boston to Philadelphia, lectures and demonstrations on topics varying from blood circulation to electricity intrigued the public. The APS sponsored astronomer David Rittenhouse's (1732–1796) public observations of the 1769 transit of Venus outside the Pennsylvania State House.

While the Revolutionary War sidelined science, it also brought the country's influential men together. The first four American presidents were members of the APS. Understanding nature and natural resources was vital to productive agriculture, and it improved manufacturing and the success of the new nation.

Thomas Jefferson became president of the APS and vice president of the United States on the same day. Natural history was his passion, and Jefferson was an avid data collector. He documented experiments with agricultural crops, including 19 varieties of peas, and compiled the first known list of North American birds using Carl Linnaeus's taxonomic naming classifications.

In 1803, Jefferson's background prompted the first governmental funding for scientific exploration. He sent the Lewis and Clark Expedition to explore the newly purchased Louisiana Territory and to collect animal and plant specimens, document soils and geology, and observe Native American agricultural practices. The APS displayed some of the Expedition's specimens.

Charles Willson Peale (1741–1827), APS member and painter, brought science to everyday people through the nation's first natural history museum.

He also introduced Jefferson to the Prussian natural history polymath, Alexander von Humboldt (1769–1859). In 1804, Humboldt was returning to Europe following a five-year expedition through South and Central America. He shared with Jefferson his observations, data collection methodologies, and bold visions on natural history.

Humboldt joined the APS, corresponding with Jefferson and other members throughout his life. His numerous books popularized natural history. Like Franklin, he presented complex science to common people. His narrative prose interlaced data with poetic descriptions. Humboldt wrote of the earth as a “living whole” where all things were interconnected—living species, the land, air, water, and climate. His interwoven web of life defines modern ecology and ecosystems.

Introducing Humboldt to the American public ushered in the era of Humboldtian science. Americans became obsessed with specimen collecting—of bird eggs, butterflies, and more. Even a teenage Emily Dickinson (1830–1886) labored over her “herbarium”—a book of pressed plants for natural history study. Humboldt’s writings inspired generations of American scientists, inventors, and writers: Samuel Morse, John James Audubon, Louis Agassiz, David Henry Thoreau, Franz Boas, and George Perkins Marsh.

Keri Dearborn

See also American Philosophical Society; Franklin, Benjamin; Lucas, Eliza; Peale, Charles Willson; Rittenhouse, David; *Vol. 1, Sec. 2*: Jefferson, Thomas; Lewis and Clark Expedition; *Vol. 1, Sec. 3*: Agassiz, Louis; Morse, Samuel F. B.

Further Reading

- Chaplin, Joyce E. 2006. *The First Scientific American: Benjamin Franklin and the Pursuit of Genius*. New York: Basic Books.
- Thomson, Keith. 2011. *A Passion for Nature: Thomas Jefferson and Natural History*. Charlottesville: University of Virginia Press.
- Wulf, Andrea. 2015. *The Invention of Nature: Alexander Von Humboldt’s New World*. New York: Alfred A. Knopf.

Onesimus (fl. 1706–1716)

The practice of inoculation came to the United States through the knowledge of Onesimus, an enslaved man owned by Cotton Mather, a prominent New England theologian and minister of Boston’s Old North Church. Little is known of when and where Onesimus was born. He appears first in American history in a note in Mather’s diary for December 13, 1706, where the minister mentions the purchase. Mather also documented the fact that he named Onesimus after a biblical slave who escaped from his master, an early Christian named Philemon.

Mather’s later diary entries detail the fact that Onesimus eventually married and had a son, Onesimus, who died in 1714. Two years later, Onesimus earned his freedom from Mather in or around August 1716 by negotiating to continue to provide services to the Mather family when needed as payment for that freedom. The two men wrote a detailed contract in which they agreed that such services would include shoveling snow, piling firewood, fetching water, and carrying corn to the mill. Onesimus also helped fund the purchase of another enslaved man, Obadiah, who could take his full-time place in the Mather home.

Onesimus remained connected to the Mather family, which benefited them in many ways, the most important being during the smallpox epidemic that swept through Boston in 1721. Mather wrote a letter to the Royal Society of London, proposing a possible way to stop the spread of the devastating disease. He called his method “inoculation” and explained that he had learned the process from Onesimus some five years earlier. At that time, Onesimus explained the practice popular in Africa and demonstrated by cutting Mather and inserting some of what he called “smallpox juice” from someone suffering the disease. Mather discovered that other Africans in Boston practiced inoculation and learned that those with a inoculation scars indicating immunity cost more in slave auctions.

Mather then advocated for public inoculations, but most doctors rejected the idea of infecting a person with smallpox. It seemed counterintuitive to their training, yet in a survey of the nearly 6,000 people who caught smallpox between 1721 and 1723, only 2 percent of the 600 Bostonians inoculated against smallpox died, while

14 percent of those who were not inoculated died. With these results, inoculation served as the most trusted way of treating the disease until English physician Edward Jenner created a vaccine in 1796.

A side story to that of Onesimus comes from the fact that the 15-year-old Benjamin Franklin witnessed this outbreak and the results of inoculation and, as an adult, became an advocate of inoculation when his own son died of smallpox.

Rosanne Welch

See also Franklin, Benjamin; *Vol. 3, Sec. 1: Smallpox, Eradication of*

Further Reading

Silverman, Kenneth. 1984. *The Life and Times of Cotton Mather*. New York: Welcome Rain.

Widmer, Ted. 2014. "How an African Slave Helped Boston Fight Smallpox." *Boston Globe*, October 17. <https://www.bostonglobe.com/ideas/2014/10/17/how-african-slave-helped-boston-fight-smallpox/XFhsMMvTGceV62YP0XhhZI/story.html>, accessed August 22, 2018.

Winslow, Ola. 1974. *A Destroying Angel: The Conquest of Smallpox in Colonial Boston*. Boston: Houghton-Mifflin.

Peale, Charles Willson (1741–1827)

Charles Willson Peale was a painter and natural history scholar during the Early Republic era of the United States. His work in natural history led to the creation of the first systematic museum of natural history and art in North America. Peale's philosophy and methodology for exhibiting natural history to the public laid the foundations for many elements of museum operations common today, while introducing the public to specimens from several scientific expeditions.

Born in 1741, Peale's family was left destitute by the death of his father when he was just eight years old. Peale and his mother moved to Chesapeake, where he attended charity school. After school, Peale was apprenticed to a saddler but quickly got into debt. To pay off his debts, Peale began painting miniature portraits, revealing an innate talent for art. During the late

1760s, Peale traveled to London to study with the artist Benjamin West. Upon returning to the United States, Peale became well known for his life-size portraits of planter society that emphasized family harmony and affectionate domestic relationships. He continued painting while serving as a militia officer during the Revolutionary War, painting over 1,200 portraits of early leaders, military heroes, important allies, and landscapes. After the war, he opened a small art museum in a wing of his home in Philadelphia.

Following the discovery of mastodon bones at Big Bone Lick in Kentucky during the 1780s, Peale acquired and displayed the bones at his art museum. His interest in natural history grew, and together with his sons, Peale united his paintings with a passion for collecting natural history specimens. By July 18, 1786, Peale had amassed a large collection of specimens and exhibited them at his own museum in Philadelphia—founding the earliest systematic museum of natural history and art in North America. Peale's museum displayed specimens according to classification principles established by Swedish scientist Carl Linnaeus in *Systema Naturae* (1735), which divided specimens into three kingdoms: animal, vegetable, and mineral. Specimens were then classified by divisions into classes, orders, families, genera, and species. Peale's collection of minerals, shells, fish, birds, insects, mammals, and ethnographic artifacts were arranged in hierarchical order, with his portraits of influential Americans as the highest level of life.

In 1801, Peale recovered two nearly complete mastodon skeletons from what is now Peale's Barber Farm Mastodon Exhumation Site near Montgomery, New York. Peale took these skeletons to his museum, where he reassembled one, sculpting the missing pieces to present the remains of an entire animal to the public. It was the second time that a fossil skeleton had been assembled anywhere, and its presence fueled debates on extinction and evolution. This display was such a success that the second skeleton was taken on tour to New York City, Pealeton, and London. Peale commemorated the discovery of the skeletons in his painting *Exhumation of the Mastodon* (1806–1808), which showed a crew of men removing bones from a marl pit.

Peale centered his museum on the philosophy of public utility, believing that museums should be based

on their capacity to educate and amuse the public. The museum was made accessible to a variety of audiences, including those of different social ranks, genders, races, political affiliations, and religions. His collection was amassed through personal effort and the solicitation of donations from the international community. He pursued an aggressive marketing campaign that focused on the economic, social, scientific, moral and religious implications of his exhibitions. Peale also instituted the sale of museum souvenirs and utilized subscription memberships to provide a steady patronage base. His philosophy was adapted by contemporary American museums and continues to be followed by many museums today.

By 1802, Peale's collections had grown to the point of needing a larger space. He received permission to use the second floor of the Pennsylvania State House (now known as Independence Hall) to merge the natural history and art collections with the symbolic center of government. The museum would move several more times during the early 1800s, due to the increasing size of its collections.

In 1818, Peale appealed to the U.S. Congress to recognize his museum as a national institution. Although the government did donate minerals and Indian artifacts from the Lewis and Clark Expedition, Congress refused to grant official recognition or funding. Because of this, Peale opted to establish the museum as a corporation with a board of directors—another model that contemporary museums adopted.

When Peale died in 1827, the museum housed over 250 quadrupeds, 1,310 birds, over 4,000 insects, 8,000 minerals, 1,044 shells, several hundred fish, and

over 200 snakes, lizards, turtles, and tortoises. It was also home to ethnographic artifacts from major scientific explorations, including the Lewis and Clark, Pike, and Long expeditions. The museum had become the primary resource for American natural history and drew public visitors from all over the world. It was depicted in one of Peale's last paintings, *Artist in His Museum* (1822), which showcased the variety of natural history specimens—including the skeleton of the mastodon he had recovered in 1801—as well as guests viewing the collections with awe.

After Peale's death, the museum was managed by Peale's son, Rubens Peale, until it declared bankruptcy in 1842. The museum's collections were dispersed, some never to be seen again—but Peale's philosophies on the purpose and functions of a museum lived on as the basis for modern American museums.

Tiffany Rhoades

See also Franklin, Benjamin; Rittenhouse, David; Winthrop, John

Further Reading

Brigham, David R. 1995. *Public Culture in the Early Republic: Peale's Museum and Its Audience*. Washington, D.C.: Smithsonian Institution Press.

Sellers, Peale Coleman. 1980. *Mr. Peale's Museum: Peale Willson Peale and the First Popular Museum of Natural Science and Art*. New York: W. W. Norton.

Wilson, Janet. 1996. *The Ingenious Mr. Peale: Painter, Patriot, and Man of Science*. Ann Arbor: University of Michigan, Atheneum Books for Young Readers.

Primary Document: Letter of Charles Willson Peale to Thomas Jefferson Regarding New Agricultural Inventions and Innovations (1815)

Soldier, scientist, and inventor Charles W. Peale carried on a correspondence with Thomas Jefferson about their mutual interests in farming and inventions. Peale's May 1815 letter, excerpted here, describes windmill sails and a corn shelling machine, as well as a discussion of the inventions and innovations that Jefferson had discussed in his previous letter. The letter suggests the wide field of interests that

men like Peale and Jefferson had, unlike the present tendency to specialize in a single field.

Belfield May 2^d 1815.

Dear Sir

Your favor of March 21st came in due time—and a rainy day now gives me leasure to write, to thank you

for your interesting letter, abounding with useful information to the farmer and Mechannic. You observe that the winter has been hard.—the Spring appears to be backward, I hope it will be favorable to our fruits, the last year gave us but little. My small green House accidentally constructed keep the Plants during the severity of the winter remarkably well. To trace a spring in my falling Garden, we had dug out a large hole in the Earth, this hole I thought if covered over might be useful to keep Turnips and other roots, therefore it was arched over, the tryal proved that it was too warm and moist, every thing of the vegetable for our tables, grew & were spoiled. I built a front, to the south, of Glass windows, in which front building are put the pots of Plants on shelves, no fire is necessary to keep Plants in such situation. The spring is covered in the cave, and the water by a trunk carried to a bason below. I believe that the springs within the Earth are all seasons of equal temperature, that our feelings induce a belief that they are warm in winter & cool in summer; the same with sellers and Caves—Perhaps a Green-house of considerable size might in this manner be constructed to save all the expence of fuel; a great quantity of air kept from impression of the external air by a thick body of Earth, would mix with the air in the front of such cave, where the necessary light must be had for Plants, But to render such Green-house complete it might be necessary to have double windows, this of course would be expensive, yet in the end a great saving, for as Doct^r Franklin said, “it is cheaper to build two Chimnies than to keep one fire”—I do not think M^r Halls invention will benifit the farmer, it is necessary to plow the land to put it [in] order for other crops, and it is also necessary to manure the whole land to fit it to nourish the long extending roots of Corn. Our land properly prepaired will produce fine Corn in rows 5 feet apart and two or 3 Grains at 2½ feet distance, which were we to place the rows 6 feet apart I suppose is planting more corn on the acre, I have made no calculation on what the difference would be. Amongst a variety of cast mould boards, I could find none of the shape of that, your plan gives, and I had, some time past, meditated making some tryal at forming a patern to get some castings made, I could not determine on the material to make the patern—I was fearful of the warping of a thin patern of wood or pasteboard, but suppose there is no difficulty of casting from another casting, If I have your permission when I receive your Plow, will get

some cast by it, that others may be benefited by getting so perfect a form to so important an Utensil as the Plow. I have conversed with many engenious farmers who have thought that they knew how to make good forms to their mould boards, some have told me that after making their mould-boards to what they thought a good form and after plowing with them, that they observed at what points was most worn, that in such places they trimed off. my oppinion is that all the Mould boards I have seen, have hollows where they ought not to be, and such hollows brake the sods in the action of turning them over, thus increase^s the labour of breaking a tough sward in addition to that of turning it over.

With respect to the springs for sails of large wind-mills, I believe there will be no difficulty, or no more than in my small ones, they must be stronger in the proportion to their office—But in a large wind-mill I would not make each sail large, no wider than the common sheet Iron, preferring such to canvis, and being painted would be very durable. The spring should be regulated by a Screw. . . .

The end of spring with a link to connect to the staple in the sail, and this staple should be placed near to the joint of the sails motion, in order to obtain only a small motion of the spring. I have found that in my first plan of making the spring work or pins, that the constant motion on the pins subjected them [to] be soon worn out, the joints of the link should be strong or with washers to prevent as little wear as possible. long and continued motion will undoubtedly wear out by friction, therefore, in such parts as can be supplied with oil from resevoirs, should be adopted to save trouble and attention, such as the Boxes of the main shaft crank, and friction wheels.

The Corn shelling machine with 2 cylinders is a good invention; and I believe will work well with a small crank receive^s its motion from the foot of the person feeding it—mine is mooved by aband from a Drum in the mill—by the weight of a log of white oak 2 feet long & 20 Inches diameter, its motion from the foot with very little exertion will be powerful enough for the shelling, the young man who made that I have, told me of their working satisfactorlily where he made them (at Columbia)—I remember seeing a machine with a single Cylinder such as you describe at the Philosophical Society, exhibited if I remember right by the inventor, but I do not remember whether it was a solid or hollow

cylinder? the objection of not adapting itself to the different sizes of Corn at the time, Struck me, and thinking to obviate this fault I thought of placing strong springs over the axis—and intending to make such a machine, I spoke of it to the young man who by chance had been employed in making those of 2 Cylinders and by his recommendation I was induced to employ him to make me one. If you wish to have one I will order one to be made. I admire the simplicity of your machine for cutting straw—that I have made must have cost me near 20\$, and it is like many other of my contrivances, costing much more than can be saved of labour in my time. the chief consolation I have that I am amused, and by that and much labour I am kept healthy and happy—My Son Franklin has commenced making Machinery for carrying on the Cotton Business, and employs his two brothers in the work. Linneus and Titian, they all possess talents for mechanic labours—Franklin in one years practice, with Mess^{rs} Hodgson, English men bred to the machine manufactory, became one of their best hands.—The Youth was always emulous to execute his work in the neatest and best manner. Every machine they make use off, must be made by themselves, I cannot afford to purchase any thing more than the materials for them to work on. . . .

At Present I have very little trouble in the Management of the farm, having two young men that take all that care & labour off my hands—my principle work is in the Garden, and to put my thorn Hedges in good order, and also to do what I find is necessary to Machinery at the Mill—I had forgot one other of my employments, namely, to oblige some few friends by my giving them the means of masticating their food. I have for many years practiced the making of artificial Teeth of a variety of Ivory & by my practice have acquired the knowledge of giving relief in some difficult cases—but as all sorts of Ivory, bones, and even shells are all subject to decay—I have lately been preparing to make some essays at making them in Enamel—for the small quantity of work that I shall ever do, perhaps it is scarcely worth the trouble & expence of making a furnace & preparing the Materials & then make many tryals before I can expect to succeed to my satisfaction. Yet if I am successfull in making a good Enamel I may give an important business to some ingenious Person who may relieve the distresses of many who want teeth for health as well as beauty. I am not unconcious that I have mispent

much of my time, a steady habit to any one object perhaps would have been more advantagous, I can reconcile this conduct to myself, because it has constituted much of my happiness—but the judicious and prudent, will condemn me! It seems almost impossible to forbear putting my hands to execute what the fancy dictates, but having frequently trifled away my time I have of late paused, and turned over in my mind the means and the end, and sought advice from my friends. Yet at this moment I am doubtful whether my actions are governed by Wisdom—I frequently think that my Pensil ought not to lay Idle. I still fancy that I could produce things worthy of notice; more valuable than my mechanic labours, By a diversity of objects, times flies swiftly away like a dream.

I turn again to your interesting letter, and think how justly you describe the principle of the Pendulum's motion, it induces a desire to see what the man has done with his Pendulum moovements. The "Ingenuous friend at Albany," I think has not made any new discovery, Cranked axle-trees have long been used to lower the Bodies of carriages, and indeed the weight being placed low, appears to be the chief principle to prevent oversetting. Turning to the copies of my letters, I find that I had described the Corn shelling Machine in my letter of Dec:r 1813. By the use of it since that period I have found it very useful, and not much liable to derangement, the space between the large Roller & the frame where the Corn passes between the two rollers, must be small to prevent the cobs from getting in & breaking them but truth in moovement & strength of parts in proportion to the power required, must always insure the just operation of a Machine. I do not know that a log turned from the centre of its groath, would in any sensible degree become untrue by shrinking—I know that the rolling-press for copper plate printing sometimes require turning anew—whether it is caused by the axis not being put in the Center of the commencement of the groath of tree, or that one side may be of a more porous substance than another and thus be a cause of becoming untrue, should that be the case I see no other resourse in the corn shelling Machine but to fix a rest, and then drive the pins most projecting from the centre of Motion.

Since writing the above I have conversed with the Person who made my shelling Machine, and he says that Apple-Tree turned, in drying becomes oval, and Hickory next, but that white-oak scarcely alters in its

form from true roundness by seasoning. He says that he has a good log, and he will make a Machine for me when I may give him notice. I have desired him to save the stuff until I can hear from you. . . .

By keeping my letter open, and now & then taking up the pen, I have touched on a variety of subjects, and now think it time to conclude, well knowing that very little is worth your time of reading it, yet I am much interested in getting an answer to some parts, especially about the final disposition of the Museum. In the last year, twice, I have been in danger by accidents, of sudden death, I promise myself in future to be cautious, in my labours, to avoid danger—But dangers may happen even with the most prudent; then how

necessary it is to be always prepared against what cannot be foreseen—The government of our Passions, and prudential care will make man last untill the machine is worn out by age; natural decay, as all nature testifies. May you my dear Sir, last untill you feel no pain in leaving this world, is the earnest prayer of

your obliged friend
C W Peale

Source: “Charles Willson Peale to Thomas Jefferson, 2 May 1815,” Jefferson Papers, Founders Online, National Archives. <http://founders.archives.gov/documents/Jefferson/03-08-02-0367>, accessed August 22, 2018.

Priestley, Joseph (1733–1804)

Joseph Priestley was a philosopher, teacher, theologian, nonconformist, and chemist. He published numerous works on the topics of religion and science; however, he is best known for discovering oxygen. A Unitarian minister and friend to Benjamin Franklin, Priestley was forced to flee England because of his radical political and religious beliefs. In 1794, Priestley relocated to Pennsylvania, where he continued his research and became an influential figure in the development of chemistry in America.

Born in a small town near Leeds, Priestley was the oldest of six children. Reared in the Calvinist faith by his aunt and groomed for the ministry, Priestley at a young age displayed advanced intellect. His inquisitive nature led him to conduct experiments with gases. In 1767, he infused water with carbon dioxide and created carbonated water. Also in that same year, he published a work on the history of electricity. In 1774, he made one of the biggest contributions to chemistry with the discovery of oxygen.

Priestley conducted a series of experiments with a mouse, a burning candle, and a mint plant. He observed how long each lasted in a sealed jar, with the plant lasting the longest. Priestley conducted additional experiments with the objects together and observed that alongside the plant, both the life of the mouse and presence of the flame were extended. Priestley continued

his research with mercury oxide and noted that the gas released was distinctly different and better than common air. These numerous experiments culminated in Priestley’s discovery of oxygen; however, he incorrectly called the newly discovered gas “dephlogisticated air.” Even though others, such as Carl Wilhelm Scheele of Sweden and Antoine Lavoisier of France, experimented with oxygen, Priestley is credited with the discovery because he published his findings first.

Moreover, Priestley’s series of experiments were groundbreaking in that it paved the way for the study of ecology. In this area of study, Priestley was ahead of his time. It would be decades later before scientists gained an understanding of the connection between living things and their environments.

In addition to chemistry, Priestley shared his views on politics and religion. He supported the American and French Revolutions and embraced a liberal interpretation of Christian dogma. Priestley’s philosophical approach to theology led him to support the Unitarian faith. His left-of-center political and religious views caused tension with politicians, scientists, clergymen, and his congregation. Because Priestley had become a controversial figure in England, he and his family were forced to move to Pennsylvania in 1794, where he remained until his death in 1804. While in America, he continued his chemistry research and helped develop the study of chemistry there.

Roshunda L. Belton

See also Rittenhouse, David; *Vol. 2, Sec. 1*: Richards, Ellen Swallow

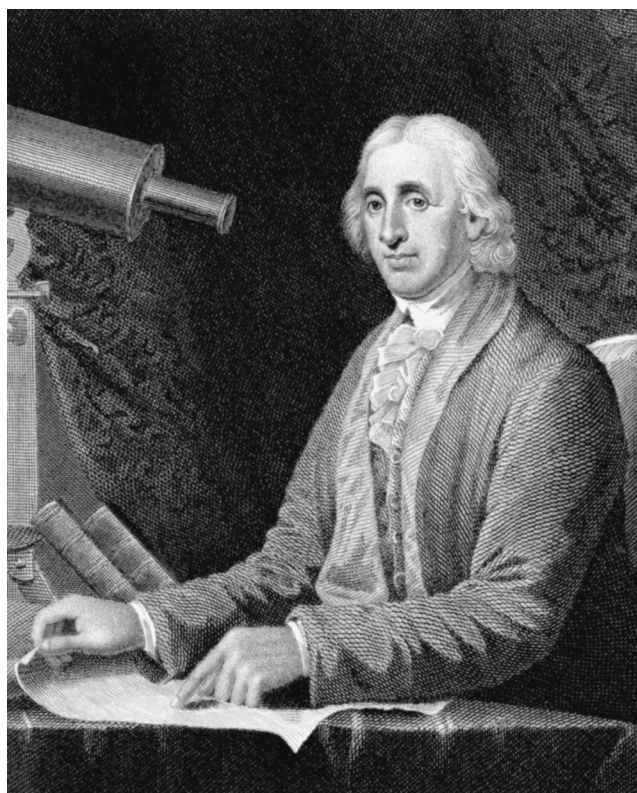
Further Reading

Jackson, Joe. 2007. *A World on Fire: A Heretic, an Aristocrat, and the Race to Discover Oxygen*. New York: Penguin Books.

Schofield, Robert. 2009. *The Enlightenment and Joseph Priestley: A Study of His Life and Work from 1773 to 1804*. University Park: Pennsylvania State University Press.

Rittenhouse, David (1732–1796)

David Rittenhouse was an important 18th-century American astronomer, inventor, and engineer. The multit talented Rittenhouse was a central figure in the development of items ranging from surveying tools to



Inventor, astronomer, and scientific instrument builder David Rittenhouse was the first director of the U.S. Mint. His Orrery, or mechanical model of the solar system, was admired by Benjamin Franklin and Thomas Jefferson. (Library of Congress)

the construction of one of the nation's first observatories.

David Rittenhouse was born on April 8, 1732, in Paper Mill Run, Pennsylvania, a small town near Germantown, itself a small town outside of Philadelphia. The son of Matthias Rittenhouse, a farmer, and his wife, the former Elizabeth Williams, Rittenhouse showed an early aptitude for math as well as exceptional mechanical skills. He also liked to tinker with farm technology and build new things. Applying those talents to books and using tools received from his uncle, Rittenhouse engaged in a process of extensive self-education. He first made mathematical instruments. He also constructed what is believed to be the first telescope built in the United States. At the same time, he established himself as a skilled maker of surveying tools. He served as the city surveyor of Philadelphia and also helped establish the boundaries of Pennsylvania, Maryland, New Jersey, New York, and the Northwest Territory.

His work in astronomy earned Rittenhouse his greatest fame within the scientific community. Among his many astronomical accomplishments was an early observation of the atmosphere of Venus. On June 3, 1769, he observed Venus's transit across the sun. He became so excited during the observation that he fainted. He also calculated the distance between the earth and the sun, coming quite close to the actual distance.

Utilizing his singular mechanical skills and mathematical knowledge, he designed numerous innovative astronomical instruments, including a pair of orreries (mechanical models of the solar system that predict the motion and positions of the planets) for what are now Princeton University and the University of Pennsylvania. His orreries could show both the lunar and solar eclipses as well as other phenomena for a period of 5,000 years. He also built an observatory on his father's farm just outside Philadelphia.

Beyond astronomy, Rittenhouse made the first man-made diffraction grating, conducted wide-ranging experiments that looked at the compressibility of water, and also considered the impact of heat on metal, wood, and magnetism. He made improvements on the famous Franklin stove and designed glasses for George Washington.

All of these efforts earned him great acclaim and recognition. In 1768, he was elected to the American

Philosophical Society, where he served as president from 1791 until his death in 1796. The recipient of numerous honorary degrees, he was recognized with membership in the American Academy of Arts and Sciences and was also named a fellow of the Royal Society in London. Rittenhouse was actively involved with higher education in Philadelphia, serving in a variety of teaching and administrative roles at both Philadelphia College and the University of Pennsylvania.

Rittenhouse played an active role in the American Revolution. Serving on the Committee of Safety, he supervised the casting of cannons, the development of rifles, and the location of both gunpowder mills and ammunition stores, as well as production of that equipment. Also, his surveying work helped the army plan defense efforts around Philadelphia. He also served in the Pennsylvania Assembly, on the War Board, and the 1776 Pennsylvania Constitutional Convention. He served the state of Pennsylvania as treasurer from 1779 until 1787, and in 1792, George Washington appointed him the inaugural director of the

United States Mint. As the mint director, Rittenhouse oversaw the minting of the first coins in the United States. He believed that coins should be beautiful and personally struck the first few, which were made from silverware donated to the mint by George Washington.

Rittenhouse married Eleanor Coulston, who died in childbirth in 1770. He married Hannah Jacobs in 1772. That union produced one child, which died in infancy. David Rittenhouse retired from the mint in 1795 and died on June 26, 1796, in Philadelphia.

William H. Pruden III

See also Franklin Stove; *Vol. 1, Sec. 2*: Diffraction Grating; *Vol. 1, Sec. 3*: Mitchell, Maria

Further Reading

Ford, J. Edward. 1946. *David Rittenhouse, Astronomer-Patriot, 1732–1796*. Philadelphia: University of Pennsylvania.

Hindle, Brooks. 1964. *David Rittenhouse*. Princeton, NJ: Princeton University Press.

Primary Document: Letter of Thomas Jefferson to David Rittenhouse (1778)

Primarily known for his work on the transit of Venus, David Rittenhouse also worked as a surveyor and state representative for Pennsylvania. In the letter here to Rittenhouse, Thomas Jefferson describes his own efforts to view an eclipse and offers advice to Rittenhouse on his astronomical clock. What is clear from the letter is that Jefferson regarded himself as a man of science and that he viewed Rittenhouse as an expert to whom he might turn for advice.

To David Rittenhouse Monticello in Albemarle, Virginia, July 19, 1778

DEAR SIR,

—I sincerely congratulate you on the recovery of Philadelphia, and wish it may be found uninjured by the enemy—how far the interests of literature may have suffered by the injury or removal of the Orrery (as it is miscalled) the publick libraries, your papers & implements, are doubts which still excite anxiety. We were much disappointed in Virginia generally on the day of the great eclipse, which proved to be cloudy.

In Williamsburgh, where it was total, I understand only the beginning was seen. At this place which is in Lat. 38 degrees-8' and Longitude West from Williamsburgh about 1 degrees-45' as is conjectured, eleven digits only were supposed to be covered, as it was not seen at all till the moon had advanced nearly one third over the sun's disc. Afterwards it was seen at intervals through the whole. The egress particularly was visible. It proved however of little use to me for want of a time piece that could be depended on; which circumstance, together with the subsequent restoration of Philadelphia to you, has induced me to trouble you with this letter to remind you of your kind promise of making me an accurate clock; which being intended for astronomical purposes only, I would have divested of all apparatus for striking or for any other purpose, which by increasing it's complication might disturb it's accuracy. A companion to it, for keeping seconds, and which might be moved easily, would greatly add to it's value. The theodolite, for which I spoke to you also, I can now dispense with, having since purchased a most excellent one.

Writing to a philosopher, I may hope to be pardoned for intruding some thoughts of my own tho' they relate to him personally. Your time for two years past has, I believe, been principally employed in the civil government of your country. Tho' I have been aware of the authority our cause would acquire with the world from it's being known that yourself & Doc't. Franklin were zealous friends to it and am myself duly impressed with a sense of the arduousness of government, and the obligation those are under who are able to conduct it, yet I am also satisfied there is an order of geniusses above that obligation, & therefore exempted from it, nobody can conceive that nature ever intended to throw away a Newton upon the occupations of a crown. It would have been a prodigality for which even the conduct of providence might have been arraigned, had he been by birth annexed to what was so far below him. Cooperating with nature in her ordinary economy we should dispose of and employ the geniusses of men according to their several orders and degrees. I doubt not there are in your country many persons equal to the task of conducting government: but you should consider that the world has but one Ryttenhouse, & that it never had one before. The amazing mechanical representation of the solar system which you conceived & executed, has never been surpassed by any but the work of which it is a copy. Are those powers then, which being intended for the erudition of the world are, like air and light, the world's common property, to be taken from their proper pursuit to do the commonplace drudgery of

governing a single state, a work which may be executed by men of an ordinary stature, such as are always & everywhere to be found? Without having ascended mount Sinai for inspiration, I can pronounce that the precept, in the decalogue of the vulgar, that they shall not make to themselves "the likeness of anything that is in the heavens above" is reversed for you, and that you will fulfil the highest purposes of your creation by employing yourself in the perpetual breach of that inhibition. For my own country in particular you must remember something like a promise that it should be adorned with one of them. The taking of your city by the enemy has hitherto prevented the proposition from being made & approved by our legislature. The zeal of a true whig in science must excuse the hazarding these free thoughts, which flow from a desire of promoting the diffusion of knowledge & of your fame, and from one who can assure you truly that he is with much sincerity & esteem

Your most obed't. & most humble serv't.
Thomas Jefferson

P. S. If you can spare as much time as to give me notice of the receipt of this, & what hope I may form of my clocks, it will oblige me. If sent to Fredericksburgh it will come safe to hand.

Source: Jefferson, Thomas. 1893. *The Writings of Thomas Jefferson, Volume 2, 1776–1781*. Paul Leicester Ford, ed. New York: G. P. Putnam's Sons, 162–64.

"Saugus Pot"

Joseph Jencks (1599–c. 1682) created a small cast-iron cooking pot known as the "Saugus pot" for the opening of the Saugus Iron Works of Lynn, Massachusetts (1642–1678). This modest kitchen pot symbolizes the birth of North America's iron and steel industry.

Cast from locally sourced bog-iron ore, the Saugus pot has a rounded silhouette, curving in before flaring out at the lip to support a lid. To modern eyes, the kettle shape suggests a witch's cauldron. Two handles support a bail to hang the pot above a kitchen fire, while three iron feet allow it to stand directly in the hearth coals.

Producing such a cast-iron pot required experienced ironworkers, highly skilled mold makers, and precision blacksmithing. Iron ore was smelted in a blast furnace to a paste-like consistency. Clay-sand molds were formed on a lathe using a pattern to insure consistency of shape for the interior and exterior. The hot metal was poured, or cast, into the single-use mold. A heated iron rod was hammered into the desired curve to form the bail and attached to the pot while still pliable.

Colonial kitchen pots ranged in size; some weighed up to 40 pounds when empty. The Saugus pot weighs just over two pounds and holds a quart of liquid. It was allegedly presented to Thomas Hudson

(c. 1590–1645), the original ironworks landowner, and passed through his family until it was presented to the city of Lynn in 1892. Scientific analysis in the 1950s validated the pot's origin and period of manufacture.

Iron pots and kettles were highly desired trade items and valuable possessions for colonial families. Colonists and Native Americans regarded cast-iron cookware as state-of-the-art culinary technology because it was durable and could sit directly in the fire, efficiently transferring heat to food without being destroyed.

Iron implements were vital to daily life and without a local foundry had to be imported from England. After previous failed attempts, the Saugus Ironworks was established along the Saugus River near abundant iron ore and available wood. Joseph Jencks, a master ironworker, was recruited from England to establish and operate the new facility with approximately 100 trained iron craftsmen.

Many scholars regard Jencks as America's first mechanical engineer. He was granted the first patent in the English colonies and infused the young iron industry with his prowess for technological innovation.

The Saugus foundry produced bar iron for other settlements and export as well as pots, hammers, and agricultural tools. Jencks harnessed waterpower to mechanize nail fabrication and draw wire to produce quantities of brass straight pins. Intricate sawmill blades were created for a hydropowered lumber mill running 20 simultaneous saws. Screws, bolts, and all manner of hardware (latches, hinges, locks and keys, etc.) were produced in this 17th-century state-of-the-art industrial facility.

Jencks's machine shop also invented a prototype fire engine, refined edged tools, and revolutionized scythe design. As natural resources dwindled and the Ironworks closed, Jencks and the men he trained went on to found ironworks throughout the colonies.

Within 100 years, Britain's North American colonies were the world's third-largest producers of iron. In 1750, Britain balked at the competition from its colonies, and trade acts forbid the production of iron goods. All smelted iron was required to be sent to England for formation into products. The iron industry was crushed economically, and technological advancement halted or went underground.

Foundry owners and ironworkers became early supporters of American independence. George Taylor (c. 1716–1781), Philip Livingston (1716–1778), and several other signers of the Declaration of Independence were connected to the iron industry. Taylor's foundries supplied the first cannonballs to the Continental army.

Keri Dearborn

See also Food Production, Native American; Franklin, Benjamin; Iron- and Silversmithing; *Vol. 1, Sec. 2: Patent and Copyright Statutes*; Three-Piece Iron Plow

Further Reading

Regan, Janet, and White, Curtis. 1954. *Saugus Iron Works: The Roland W. Robbins Excavations, 1948–1953*. Washington, D.C.: National Park Service.

Woodbury, C. J. H., and John E. Hudson. November 21, 1892. "Addresses at the Presentation to the City of Lynn of the First Casting Made in America." In *The Saugus Iron Works at Lynn, Mass.* Lynn, MA: Press of Thos. P. Nichols.

Schooner

A schooner is a sailing boat rigged with fore-and-aft sails. The foremast is shorter than the mid and aft masts. Early schooners were made with two masts, but modern schooners come in a variety of mast combinations. To be considered a schooner, a ship must have two or more masts; the front (fore) mast is shorter than the rear (aft) mast, and the mainsail is attached to the aft mast. The vessels are usually fore and aft rigged, meaning that the sails are parallel to the body. Fore and aft rigs are used mostly when the vessel is sailing a coast. Other vessels with more than one mast are usually square-rigged, meaning that they have sails that are principally positioned perpendicular to the body of the vessel. The square rig is used when going on long voyages across the ocean. Schooners were more widely used in the United States than in any other country. Steam-powered vessels caused the schooner to decline.

The schooner evolved from a Dutch fishing craft in the 1600s. Schooners originated at Gloucester,

Massachusetts. They were used in coast-wide trade where speed was necessary. Very few vessels could match the speed and versatility of the schooner. It was used as a fishing boat, and because of its speed quickly became popular among smugglers and was even used as a pirate ship and warship. In the late 19th century, the schooner was one of the most widely used cargo vessels of all time, transporting anything from coal, lumber, granite, ice, and limestone. The versatility of the schooner has been proven again and again with its capability to withstand time and the elements. The advantage of the schooner rig, because its sails run the length of the deck, is that the ship can catch the wind at a better and much closer angle. This means that it doesn't need to tack as often and can sail right into a port at closer quarters. The sails can also be used on small vessels as well as larger vessels.

Schooners were made for coastal sailing. They can deal with a variety of different wind types and do well in shallow water. The schooner was small compared to other vessels, which meant that it required a smaller crew to operate and therefore much more economical. Also, the fore and aft sails were easier to hoist up from the deck, and there was no need to have many men climb up to unfold the mast or reefing. By the beginning of the 18th century, the schooner was being used by colonial fisherman in New England because of its combination of speed, maneuverability, and economy. By the mid-18th century, the schooner became the predominant vessel for fishing and coastal trading in European waters. The ship's continued development aimed at increasing speed, allowing fishermen to catch more fish and make more money. Fisherman would race to get back to the fish auctions to get the best prices.

Also, because of its speed, the schooner became very popular with smugglers and pirates because they could get away from larger and slower British naval vessels. Shipbuilders in Maryland and Virginia modified schooners for smugglers so that they could sail into small coves. They also added square rigs on top of the mast to add extra speed. These were known as the first American-built schooners, and they were known as the "Virginia models."

Today, these ships are mostly used for private sailing and commercial party ships. Cruise lines take customers out on schooners for day trips. Schooners are

also still raced. In 1990, schooner racing began in Chesapeake Bay. The fastest sailing ship to cross the Atlantic was the schooner yacht *Atlantic*. It was built in 1903 and famously raced in 1905, crossing the ocean in 12 days, four hours, and one minute. The *Atlantic* averaged over 200 miles per day.

The schooner is considered the sturdiest wooden ship of all time. Although schooners are not used for trade today, there is some talk of reverting to wind-powered schooners in the wake of a wave of shipping company bankruptcies driven in part by the high cost of fuel.

Michael David Martinez

See also Vol. 1, Sec. 2: Charting the Gulf Stream; Practical Ocean Navigation; Steam Engine; Steamboat

Further Reading

- Follansbee, Joe. 2006. *Shipbuilders, Sea Captains, and Fishermen: The Story of the Schooner Wawona*. Bloomington, IN: iUniverse.
- Greenhill, Basil. 1980. *Schooners*. New York: Harper-Collins Distribution Services.
- MacGregor, David R. 1982. *Schooners in Four Centuries*. London: Model & Allied.
- MacGregor, David R. 2001. *The Schooner: Its Design and Development from 1600 to the Present*. Annapolis, MD: Naval Institute Press.

Silversmithing. See Iron- and Silversmithing

Smallpox Inoculation

Smallpox was a deadly disease caused by the variola virus. Where it originated is unknown, but an area such as Egypt's Nile and/or India's Ganges river valleys are likely candidates, as they were densely populated enough for it easily to pass from person to person. From there, the illness probably made its way into southwestern Asia. By the 16th and 17th centuries, it had spread to most of the inhabited world, and by the end of the 18th century, smallpox had been established as a major killer, responsible for about 12 percent of all deaths and about 30 percent of deaths of urban children.

Symptoms included a high fever and a rash that turned into sores, which broke open and released more of the virus. The sores scabbed over and healed, often leaving severe scars. As many as 30 percent of survivors were left blind, and about 30 percent of victims died.

As early as the 10th century, it was noted that people who survived smallpox never caught it again. From there, a practice called “variolation” began. Named after the virus itself, variolation involved making a scratch in the skin of a healthy person and introducing material from a lesion on a patient with active smallpox, which caused a less severe form of the illness. Problems with this method included patients being just as contagious as if they had acquired the disease naturally, and nearly 2 percent of those who tried variolation died.

Variolation remained in place as the most effective means of controlling the illness until an English country doctor named Edward Jenner, though a series of observations and experiments, made a remarkable advance in the science of inoculation.

Edward Jenner was born May 17, 1749, in Berkeley, Gloucestershire, England. At the age of eight, he underwent the experience of variolation himself, which, while unpleasant, was effective (and perhaps a reason for his interest in investigating a better way to protect against smallpox). Jenner developed a strong interest in science and nature and at age 13 was apprenticed to a country surgeon in Sodbury, near Bristol. It was there that Jenner first heard a dairymaid say that she would never be a victim of smallpox because she had had cowpox, a similar but much milder illness contracted from milking cows that had an active infection on their udders. A typical case of cowpox in a human would result in sores on the hands and lower arms but was rarely if ever passed from one person to another. It was a common belief at the time that dairymaids were in some way protected from smallpox, but it would take Jenner’s later work for this to be proven true.

Upon completion of his apprenticeship at the age of 21, Jenner became the student of a well-known and respected surgeon named John Hunter, who was on the staff of St. George’s Hospital in London. Hunter passed along his expertise in experimental science, which would prove useful in many of Jenner’s later endeavors. In 1773, after two years of training with

Hunter, Jenner returned to his hometown of Berkeley to practice medicine, where he turned his thoughts once again to smallpox.

In his medical practice, he made note of people whom he inoculated against smallpox using the variolation process but who had not shown any signs of illness in response, as would normally be expected. Upon questioning, he found that these people had had cowpox, often many years earlier. He gradually compiled the evidence to support his theory that cowpox could protect against smallpox, eventually gathering a list of 31 individuals. He then set out to do a test himself.

In May 1796, Jenner found a dairymaid, Sarah Nelms, who had fresh cowpox lesions on her hands and arms. Using material from Nelms’s lesions, he inoculated an eight-year-old boy, James Phipps. The boy initially developed mild fever. Nine days after the procedure, he felt cold and had lost his appetite but had recovered by the following day. In July 1796, Jenner inoculated the boy again, this time with matter from a fresh smallpox lesion. No disease developed, and Jenner concluded that protection was complete.

Jenner continued to collect evidence and completed a second trial of his inoculation process in at least 10 people in March and April 1798. That same year, he published a paper titled “An Inquiry into the Causes and Effects of the Variolae Vaccinae, a disease discovered in some of the western counties of England, particularly Gloucestershire and Known by the Name of Cow Pox.” The Latin word for cow is *vacca*, and the cowpox virus is *vaccinia*; this is how Jenner decided to call his new procedure “vaccination.”

Jenner then set out to further publicize his procedure. In London, vaccination became popular through the activities of colleagues, some of whom he supplied with the material he used to vaccinate his own patients.

Jenner then conducted a nationwide survey to collect even more evidence that cowpox could protect against smallpox. The results of this survey confirmed his theory, and after that, vaccination spread rapidly in England. By the year 1800, it had reached most European countries.

Although he received worldwide recognition and honors, Jenner made no attempt to profit from his discovery. He devoted so much time to the cause of vaccination that his private practice suffered, and the British

Parliament, in recognition of his contribution, awarded him grant money. He continued to see patients and vaccinate poor children for most of the rest of his life. Jenner died on January 26, 1823, at the age of 73.

Nancy Beach

See also *Vol. 3, Sec. 1: Smallpox, Eradication of*

Further Reading

Baxby, D. 1999. "Edward Jenner's Inquiry; A Bicentenary Analysis." *Vaccine* 17: 301–7.

Fenner, Frank, Donald A. Henderson, Isao Arita, Zdenek Jezek, and Ivan Danilovich Ladnyi. 1988. *Smallpox and Its Eradication*. Geneva, Switzerland: World Health Organization. <http://apps.who.int/iris/handle/10665/39485> (link no longer active).

Riedel, S. 2005. "Edward Jenner and the History of Smallpox and Vaccination." *BUMC Proceedings* 18: 21–25.

"Smallpox Basics." Centers for Disease Control and Prevention. <http://emergency.cdc.gov/agent/smallpox/disease/> (link no longer active).

Primary Document: George Washington's Order for All Soldiers to Receive a Smallpox Inoculation (1778) and Letter of Edward Rowse to Thomas Jefferson Suggesting the Possibility of Vaccines for Other Diseases (1805)

The following is General George Washington's general order from March 18, 1778, ordering all soldiers who had not yet been inoculated to report to the regimental surgeon. Historians credit Washington's decision to vaccinate his troops against smallpox as one of the reasons that the Continental Army won the Revolutionary War. Also included is Edward Rowse's 1805 letter to Thomas Jefferson in which he says that the efficacy of smallpox vaccinations suggest that vaccines for other diseases might also be effective.

George Washington's Order

Head-Quarters V. Forge Wednesday March 18th 1778.

Parole: Steuben—Countersigns: Sheffield. Scarborough.

Innoculation for the Small-Pox having been happily performed on all the subjects in Camp it is necessary to guard against the fatal effects of that disorder taken in the natural way, The Commander in Chief therefore enjoins all officers commanding Regiments upon the arrival of recruits or return of absent soldiers to make immediate and strict inquiry whether they have had the Small-Pox, and order such as have not to be innoculated without loss of time by the Regimental Surgeon; and in case of the Regiments being unprovided with one to give instant notice to the Surgeon General.

The men ordered yesterday for His Excellency's guard are to parade tomorrow morning at guard-mounting on the grand-parade.

Source: *The Writings of George Washington, Volume 11, May 1, 1775–May 31, 1778*. Washington, D.C.: Government Printing Office, 1934, 107.

Edward Rowse to Thomas Jefferson

Boston 13th. July 1805 No. 7 Warren Street

SIR

The late discoveries in England and Turkey of the beneficial effects of the kine pox, as an effectual preventive remedy, for the diseases of the small pox, and the plague; have irresistably led me to the following reflections.

The characteristics, that belong in common to both these complaints; appear to be—a power of seizing the human species but partially; by succeeding in their attacks on some, but becoming repulsed by others—of appearing only in hot weather; with a few exceptions to the small pox—when the putrescent tendency of the fluids, is most increased by heat—and, that they are both fevers; the one eruptive, and the other putrid.

From this data; the cause of the beneficial effects of the vaccine innoculation, appears probable to be owing to some partial change of the fluids of the constitution, that the subject undergoes, approaching to the less putrefactive state of the fluids of the graminivorous animal, from whom the remedy is taken; that secures him uninjured, from the subsequent morbid attacks of these diseases; either, in inhaling an

atmosphere impregnated with their effluvia, or in an inoculation of their diseased matter.

However, as the vaccine inoculation is *proved* to be a remedy against two violent fevers—the small pox, being commonly violent, when commencing without inoculation; it is no more than reasonable to infer, that, against other fevers of a similar nature, it will produce the same effect!—And, but few will venture to assert, that the small pox and plague, are more similar, than, the plague and yellow fever!

I cannot therefore, help being of the opinion, that it is likely to prove a remedy also; for this formidable calamity of the western world.

It would give me great happiness, to become the fortunate man of accelerating the discovery of a remedy, for so great an evil.

The most satisfactory trial of it, would be, by inoculating the matter of the yellow fever on a subject, that has been prepared for it, by the vaccine inoculation; but the danger that must attend the experiment, may be considered as putting it out of the power of any one to try it, yourself alone excepted, by having the lives of condemned criminals at your

disposal.—Which necessitates me to trouble you with the affair.

I conclude it is unnecessary to send you a detail of the effects of the vaccine inoculation against the plague, as it has passed into most of the papers of the States.

I shall be obliged to you to inform me whether you think favorably enough of it, to induce you to give it a trial. You will also much increase the obligation, by informing me of the present condition of the breed of Arabian horses in Virginia; and to what degree they have arisen, as an article of comm[erce?] since the account you published of them, in your Notes on that State: And of the original stock was imported from south Arabia.

With the highest esteem, I have the honor to be
Sir, your most obedient Servant
EDWD ROWSE

Source: Rowse, Edward to Thomas Jefferson, July 13, 1805. Founders Online, The Papers of Thomas Jefferson, National Archives. <http://founders.archives.gov/documents/Jefferson/99-01-02-2083>, accessed August 22, 2018.

Spinning Wheel

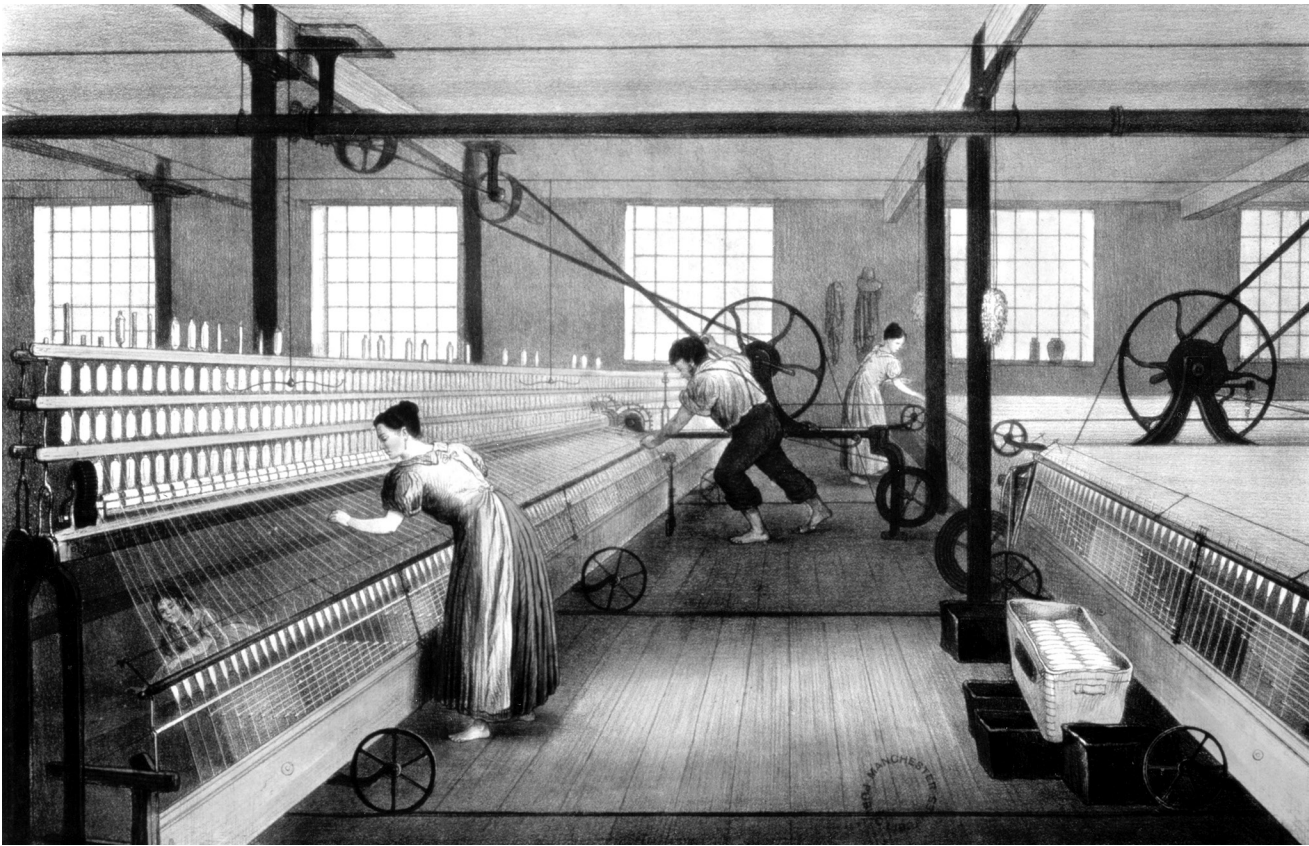
The exact origins of the spinning wheel, a device used to turn natural fibers into usable thread, are unknown, but the apparatus that would be recognizable as the spinning wheel in use in early America appears to go back to 13th-century Europe. The first forerunner to the wheel was the handheld spindle, a tool that appears to have originated in India as early as 500 BCE. Today, many modern spinners first learn to turn fiber into yarn with a handheld spindle.

While the spinning wheels in use through history have varied in style depending upon the area of the world in which they were used, the basic mechanism remained the same: raw fiber was held on a spindle that was turned by a mechanism powered by a large wheel operated by a person called the spinner. As the fiber came off the turning spindle, the spinner manipulated it, twisting the strands into yarn that was then woven into fabric. Improved versions of the spinning

wheel included a foot-operated treadle, leaving both of the spinner's hands free. Variations in wheel designs made them suitable for different fibers; flax required a different wheel from wool and cotton, which could both be spun on the same style of wheel.

The spinning wheel was ubiquitous in the early American household. In that era of gender-specific work roles, women and girls spun the yarn, while loom operation was considered a man's job. At that time, the term "spinster" was a compliment, as a "spinster" connoted a woman who spun with great skill and productivity. As the essential partner to her husband, the "goodwife" was expected to be a proficient, if not expert, spinster.

The spinning wheel is historically significant in America for a number of reasons. First, it allowed early colonists to cover and clothe themselves at a time when manufactured fabrics were unavailable or prohibitively expensive. It also represents the importance of "women's work," of which spinning was only one essential part. In



While the phrase “spinning wheel” conjures up images of a one-wheeled apparatus, the water- or steam-powered factory spinning wheel, invented by Richard Roberts in 1825, revolutionized textile production. Textile factories also changed the way workers interacted with their product, transforming skilled workers into low-waged, unskilled workers. (Ann Ronan Pictures/Print Collector/Getty Images)

addition, the manual spinning of fiber into thread was a forerunner of the American textile industry, which emerged in the post-Revolutionary era.

Early American colonists manufactured most of their textiles at home. The making of fabric involved a bewildering number of steps, beginning with the cultivation of the plant or animal that provided the fiber. In the earliest period, women most often worked with fibers produced from the flax plant. At that time, settlers were still in the process of clearing land and eliminating predators to prepare for the farming of sheep. Only with the arrival of sufficient numbers of sheep in the colony could colonists begin to produce woolen yarn for textiles. Cotton spinning did not commence in great volume until after 1793 and the invention of the cotton gin. While the production of all fibers was complicated and time-consuming, the cost and limited

availability of imported fabrics made their purchase prohibitive for the majority of colonial Americans.

As the colonies developed and imported textiles became more readily available and affordable, women began to drift away from the spinning wheel, and its importance diminished. The American Revolution and the advent of boycotting and nonimportation agreements prompted the resurgence of interest in spinning and home manufacture of textiles, encouraging women to get their old wheels down from the attic. Some women’s groups even provided classes for younger ladies and girls who had grown up at a time when spinning was no longer a required art; others spun thread, produced cloth, and sewed shirts for Continental soldiers.

The end of the Revolutionary War marked the demise of the mercantile system, the prohibition of finished goods for trade, and consequently the beginning

of the textile industry in the United States. Power thread and textile mills replaced hand spinning and weaving. In 1793, Samuel Slater built the first American mill for spinning thread, and by 1821, the famed mill town of Lowell, Massachusetts, had begun production of textiles. The Slater and Lowell mills represent only two of the numerous textile mills in operation in the United States by the 19th century. Encouraged by Eli Whitney's 1793 invention of the commercially viable cotton gin, cotton culture expanded in the South, hand in hand with more efficient and cost-effective production of cotton yardage in the Northeast.

The spinning wheel's use in the American colonies helped to sustain colonists' ability to clothe themselves, promoted patriotism during the Revolutionary War, and

supported the establishment of trade industry in the Early Republic. Its descendant, the power textile mill, firmly established the textile industry in the 19th century, further solidifying the United States' role in international trade and strengthening the American economy.

Lee Smith

See also *Vol. 1, Sec. 2*: Lowell Mill System; Milling Machine; Whitney, Eli

Further Reading

Wosk, Julie. 2003. *Women and the Machine: Representations from the Spinning Wheel to the Electronic Age*. Baltimore: Johns Hopkins University Press.

Primary Document: An "Address to the Ladies" Urging American Women to Boycott British Goods (1767)

The spinning wheel became a significant symbol of the American Revolution as women rejected British-made textiles and urged those with a revolutionary bent to spin and weave their own cloth as part of a nonconsumption movement. The "Address to the Ladies" seen here appeared in Boston newspapers in 1766 and 1767 to encourage women to boycott British goods and wear homespun fabrics, highlighting the political importance of the spinning wheel.

Address to the LADIES.

*Young ladies in town, and those that live round,
Let a friend at this season advise you:
Since money's so scarce, and times growing
worse
Strange things may soon hap and surprize you:
First then, throw aside your high top knots of
pride
Wear none but your own country linnen;
of Oeconomy boast, let your pride be the most
What, if homespun they say is not quite so gay
As brocades, yet be not in a passion,
For when once it is known this is much wore
in town,*

*One and all will cry out, 'tis the fashion!
And as one, all agree that you'll not married be
To such as will wear London Fact'ry:
But at first sight refuse, tell'em such you do
chuse
As encourage our own Manufact'ry.
No more Ribbons wear, nor in rich dress appear,
Love your country much better than fine things,
Begin without passion, 'twill soon be the
fashion
To grace your smooth locks with a twine
string.
Throw aside your Bohea, and your Green
Hyson Tea,
And all things with a new fashion duty;
Procure a good store of the choice Labradore,
For there'll soon be enough here to suit ye;
These do without fear and to all you'll appear
Fair, charming, true, lovely, and cleaver;
Tho' the times remain darkish, young men may
be sparkish.
And love you much stronger than ever. !*

Source: *The Boston Post-Boy & Advertiser*, Number 535, November 16, 1767.

Street Lighting

Street lighting in towns and cities dates to the mid-1600s. Benjamin Franklin designed and oversaw the installation of streetlights in Philadelphia in 1757. Cities in the American colonies such as Boston, Philadelphia, and New York already had streetlights, but Franklin's design is generally considered a great leap forward in street lighting technology. Electric streetlights first appeared in 1889 and are now widely used in American towns and cities.

Cordova, in the Moorish territory in Spain, was the earliest city to have fixed streetlights with candles in the mid-17th century, followed by London in the early 18th century. Within a few decades, they were available in the major cities of the American colonies. The earliest colonial era streetlights were lit by candles placed inside a glass vessel, which kept the candle from being blown out by wind.

Although Franklin was not the first to propose street lighting, he materially improved the old London globes that were used for lighting streets at that time. On March 9, 1756, the Pennsylvania Assembly passed Franklin's bill for providing night watchmen and street lighting for Philadelphia. In his autobiography, Franklin credits another Philadelphian, John Clifton, for introducing the utility of streetlights by being the first to place one outside his door. They were sometimes hung from buildings or poles in the streets or on pumps. By 1767, there were 320 lamps for a population of 26,000 living in Philadelphia. The fines for breaking such lamps grew from 40 shillings in 1751 to £20 via the Act of 1771.

Franklin designed a lamp of four flat panes with a funnel above to draw up the smoke, and crevices admitting air below to assist the ascent of the smoke. This way, they were kept clean and did not go dark in a few hours, as the London globe lamps did. Additionally, when there was an accident, instead of replacing the whole globe, only a single pane had to be replaced. The new whale oil streetlights also kept the streets illuminated much longer, helping to dramatically reduce murder rates in Philadelphia. Franklin mentioned these innovations to Dr. John Fothergill, an English physician and scientist, who had earlier

written a preface to Franklin's writings on electricity. Reproductions of the Franklin lamp are still in use today around Independence Hall and other museums in Philadelphia.

With the invention of gaslights by William Murdoch in 1792, more cities in Europe began lighting their streets, gas being both cheaper and brighter than candles. In 1816, Baltimore was the first American city to use gaslights to light its streets. Gaslights remained popular throughout the 19th century in the United States. Thomas Edison pioneered the electric lightbulb, which considerably improved streetlight technology. On March 31, 1889, Wabash, Indiana, became the first electrically lit city in the world. Fluorescent and incandescent lights grew in popularity in the 1930s and 1940s and were made mostly by General Electric and Westinghouse.

Abhijit Roy

See also Franklin, Benjamin; *Vol. 2, Sec. 2*: Subway System of New York City

Further Reading

- Chaplin, Joyce. 2007. *The First Scientific American: Benjamin Franklin and the Pursuit of Genius*. New York: Basic Books.
- Koslofsky, Craig. 2002. "Court Culture and Street Lighting in Seventeenth-Century Europe." *Journal of Urban History* 28, no. 6: 743–68.
- Mumford, Michael D. 2002. "Social Innovation: Ten Cases from Benjamin Franklin." *Creativity Research Journal* 14, no. 2: 253–66.

Swim Fins

Benjamin Franklin was associated with many inventions—but his first was a pair of swim fins, which he invented when he was 11 years old. Growing up in Boston, Franklin loved the water—specifically the Charles River, the Atlantic Ocean, and Boston Harbor, and he often dreamed of becoming a sailor. He learned to swim by himself and also taught his playmates, using the fins in the pond in Boston Common. He later used kites, and holding one aloft, he floated on his

back and let it pull him. He had another boy carry his clothes to the other side of the pond while he swam across it using his fins and kite.

Franklin's first lessons in swimming were from one of the first books on the subject, *The Art of Swimming*, written in 1696 by Melchisedec Thevenot, a Frenchman, who helped popularize the breaststroke. Franklin toyed with ways to make himself go faster. He observed that the limit to how much water one could push and hence one's propelling power was a function of the size of one's hands and feet. To increase his speed while swimming, he devised fins that he wore on his hands. They were made of wood and were oval, like lily pads or an artist's paint palette, and helped the swimmer attain greater speed with each stroke. They were roughly 10 inches long and about 6 inches wide, and they had a circular opening where the thumb could be placed to hold on to the pad. He also fitted the soles of his feet with a kind of swimming sandal. In 1773, Franklin wrote about his first invention, noting that while the fins did increase his speed, they fatigued his wrists. He was also unhappy with the foot fins, noting that the inside of the foot was as important in swimming as the sole.

While living in London, Franklin used his fins while swimming a few miles in the Thames River. He considered opening a school for the instruction of swimming in the city but decided against it. In his 1749 essay, "Proposals relating to the education of youth in Pennsylvania," he proposed swimming be a part of the curriculum, an unheard-of idea in the 18th century. One of the people he taught to swim in London was a fellow young printer named Wygate, who proposed that the two of them travel around Europe as journeymen printers and swimming instructors. Franklin considered the idea but was persuaded by Thomas Denham, a Quaker merchant, to return to Philadelphia and serve as his clerk for £50 a year.

Franklin's first invention did not really catch on with the American or European publics, who regarded swimming with great skepticism. Swim fins are popular today—modern versions have been created for paddle boarding and body surfing as well as for competitive swimming practice. Franklin's advocacy for swimming was recognized over two centuries later when he

was inducted into the International Swimming Hall of Fame in Fort Lauderdale, Florida, in 1968.

Abhijit Roy

See also Franklin, Benjamin

Further Reading

- Flemming, Candace. 2003. *Ben Franklin's Almanac: Being a True Account of the Good Gentleman's Life*. New York: Simon & Schuster.
- Goodman, Nathan G. 1931. *The Ingenious Dr. Franklin: Selected Scientific Letters of Benjamin Franklin*. Philadelphia: University of Pennsylvania Press.
- Isaacson, Walter. 2003. *Benjamin Franklin: An American Life*. New York: Simon and Schuster.

Three-Wheel Clock

Ben Franklin invented a 24-hour, three-wheel clock, which was much simpler than the typical clock designs of the time. This clock, like others in the 18th century, had only an hour hand. Minute hands were added to clocks much later.

Franklin did not write a description of the clock that he had devised. James Ferguson (1710–1776), an astronomer, mathematician, and horologist who had also published Franklin's magic squares and magic circles, published a design for the clock in 1773, probably unbeknown to Franklin at the time. When Franklin discovered Ferguson's improvements, he was delighted. The clock was often called "Ferguson's clock" and was an improvement on a single handed clock that Franklin had invented and was known as "Franklin's clock."

Ferguson credited Franklin for creating a clock showing hours, minutes, and seconds and having only three wheels and two pinions in the whole movement. The hours were engraved in spiral spaces along two diameters of a circle containing four times 60 minutes.

The clock could operate for up to 30 hours at a time. Ferguson noted that several clocks had been made according to Franklin's specifications and that they measured time remarkably well. He, however, pointed out two limitations in Franklin's version of the clock: a) it required rewinding more than once a week, and b) the

hand of the clock could not be upon any hour without being over four hours at the same time. He modified the clock by having only the minutes of one hour shown on the single dial, and small segments of revolving plates, set behind the dial and bearing numbers for the hours and seconds, appeared through small apertures in it.

He showed it to Franklin, who approved of the alterations. Ferguson also devised a clock showing motions of the sun and moon and the times of high and low tide. Franklin had John Whitehurst of Derby, England, construct clocks for him on these designs.

Three-wheel clocks still exist today, both centuries-old originals and as reproductions.

Abhijit Roy

See also Franklin, Benjamin; *Vol. 1, Sec. 2*: Banjo Clock

Further Reading

Cohen, I. Bernard. 1945. "How Practical Was Benjamin Franklin's Science?" *Pennsylvania Magazine of History and Biography* 69, no. 1945: 284–93.

Ferguson, James. 1778. *Select Mechanical Exercises: Shewing How to Construct Different Clocks, Orreries and Sun Dials, on Plain Easy Principles*. 2nd ed. London, 1–4.

Isaacson, Walter. 2003. *Benjamin Franklin: An American Life*. New York: Simon and Schuster.

Primary Document: James Ferguson's Description of Benjamin Franklin's Three-Wheel Clock (1773)

Astronomer and mathematician James Ferguson published a description of Benjamin Franklin's three-wheel clock in 1773, in great part because Franklin did not do so himself. The three-wheel clock was regarded as a great improvement on single-wheel clocks.

A Clock shewing the Hours, Minutes, and Seconds, having only three Wheels and two Pinions in the whole Movement. Invented by Dr. FRANKLIN of Philadelphia.

The dial-plate of this clock is represented by Fig. 1. of Plate I. The hours are engraven in spiral spaces, along two diameters of a circle containing four times 60 minutes. The index *A* goes round in four hours, and counts the minutes from any hour it has passed by, to the next following hour. The time, as it appears in the figure, is either 32½ minutes past XII, or past IIII, or past VIII; and so on in each quarter of the circle, pointing to the number of minutes after the hours the index last left in its motion. Now, as one can hardly be four hours mistaken in estimating the time, he can always tell the true hour and minute, by looking at the clock, from the time he rises till the time he goes to bed. The small hand *B*, in the arch at top, goes round once in a minute, and shews the seconds as in a common clock.

Fig. 2. shews the wheel-work of this clock. *A* is the first or great wheel, it contains 160 teeth, goes round

in four hours, and the Index *A* (Fig. 1.) is put upon its axis, and moved round in the same time. The hole in the index is round, it is put tight upon the round end of the axis, so as to be carried by the motion of the wheel, but may be set at any time to the proper hour and minute, without affecting either the wheel or its axis. This wheel of 160 teeth turns a pinion *B* of 10 leaves; and as 10 is but a 16th part of 160, the pinion goes round in a quarter of an hour. On the axis of this pinion is the wheel *C* of 120 teeth; it also goes round in a quarter of an hour, and turns a pinion *D*, of 8 leaves, round in a minute; for there are 15 minutes in a quarter of an hour, and 8 times 15 is 120. On the axis of this pinion is the *second-hand B* (Fig. 1.) and also the common wheel *E* (Fig. 2.) of 30 teeth, for moving a pendulum (by pallets) that vibrates seconds, as in a common clock.

This clock is not designed to be wound up by a winch, but to be drawn up like a clock that goes only 30 hours. For this purpose, the line must go over a pulley on the axis of the great wheel, as in a common 30 hour clock. Several clocks have been made according to this ingenious plan of the Doctor's, and I can affirm, that I have seen one of them, which measures time exceedingly well. The simpler that any machine is, the better it will be allowed to be, by every man of science.

Source: Ferguson, James. 1823. *Essays and Treatises*. Edinburgh: Stirling & Slade, 199–200.

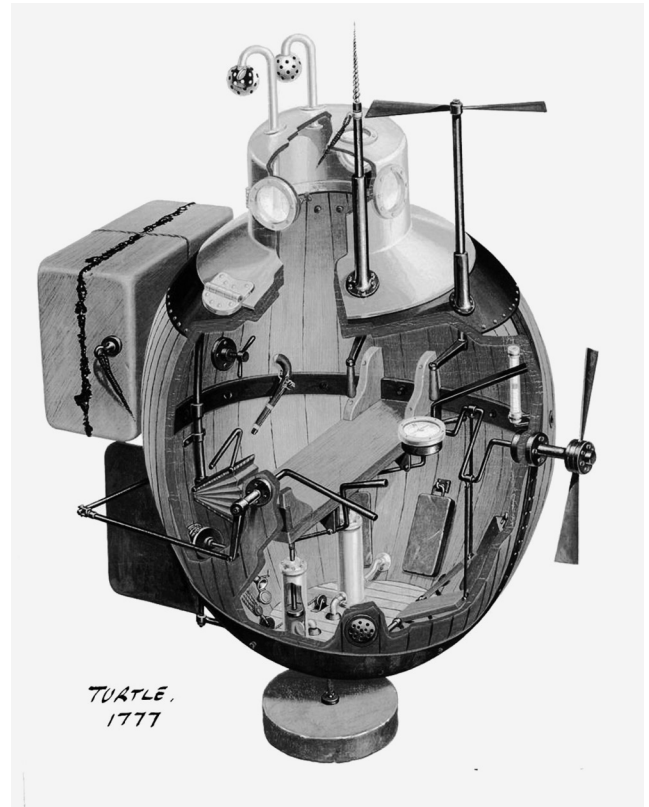
Turtle Submarine

The *Turtle*, named for an appearance similar to its namesake, was the world's first submersible with a documented record of use in combat. It was deployed by the Continental Army in 1776 to attack British ships in New York Harbor during the American Revolution. Although the attack failed, the world was put on notice that naval warfare would no longer be confined to the water's surface.

The *Turtle* was the brainchild of David Bushnell, a Yale University student. Bushnell equipped the *Turtle* to dive by flooding a compartment with water, and then to surface by forcing the water out by using a hand pump. The underwater craft featured propellers to allow it to travel up and down as well as backward and forward, reaching speeds of nearly three miles per hour. Built from sturdy wood that was sealed with tar to prevent leaks, and internally braced by a heavy steel ring, the *Turtle* was 6 feet high, 10 feet long, and 3 feet wide. Lighting was provided by six small pieces of glass, and air entered the chamber through two snorkels until the craft slipped below the surface. Once it was submerged, there was enough air for a 30-minute mission, and in the darkness the directional gauges were illuminated by bioluminescent foxfire.

But what made the *Turtle* lethal was its weapons package. It carried a time bomb attached to its hull, which could be secured to an enemy ship. A clockwork mechanism would allow the sub to leave the area before the explosion was triggered.

The *Turtle* saw its first and only action on the night of September 6, 1776, when it entered New York Harbor with orders to destroy the HMS *Eagle*, the flagship of British Admiral Richard Howe. Howe's squadron had taken control of the harbor and was protecting British forces coming ashore. Ezra Lee, a sergeant in the Continental Army, was piloting the *Turtle* and spent most of the evening trying to get close enough to the *Eagle* to attach his explosive charge, but without success. As dawn approached, and fearing detection, Lee broke off the attack but was discovered by British sailors, who gave chase in a rowboat. He jettisoned the time bomb, which exploded; the resultant commotion provided the diversion he needed to escape. But escape was only temporary. The following month, British warships attacked and sank the tender ship carrying



The iconic *Turtle* was the first submersible craft used in combat. David Bushnell built the *Turtle* in 1775 to attach explosive charges to British ships in the New York harbor. Bushnell's submersible craft failed to sink any ships, but it began the race to build a working military submarine. (Drawing courtesy of John Batchelor/Department of the Navy)

the *Turtle*. Bushnell reportedly salvaged what was left of his submarine, but no one knows for sure what happened next. News of its return to the Revolutionary War never surfaced, and Bushnell spent the rest of the conflict building exploding mines that could be floated out to sea to attack British ships. Anyone interested in seeing what the *Turtle* looked like can see a life-size replica at the Submarine Force Library and Museum in Groton, Connecticut.

John A. Morello

See also Bushnell, David; Vol. 1, Sec. 2: Amphibious Steam Vehicle

Further Reading

Diamant, Lincoln. 2004. *Chaining the Hudson: The Fight for the River in the American Revolution*. New York: Fordham University Press.

Primary Document: Letter of David Bushnell to Thomas Jefferson Regarding Bushnell's Experiments with Submarines (1787)

Described by George Washington as an "effort of genius," the Turtle submarine was designed to break the British blockade of the colonies. Though its military contributions were minimal, it was nonetheless the world's first combat submersible. In 1787, David Bushnell, inventor of the submarine, and Thomas Jefferson exchanged letters about the Turtle. Bushnell wrote a long letter explaining both how the machine was constructed and how it responded to testing. The excerpt here is about experiments that Bushnell conducted.

"Experiments made to prove the nature and use of a Submarine Vessel."

No.3.

The first experiment I made, was with about two ounces of gunpowder, which I exploded four feet under water, to prove to some of the first Personages in Connecticut, that powder would take fire under water.

The second experiment was made with two pounds of powder, inclosed in a wooden bottle, and fixed under a hogshhead, with a two inch oak plank between the hogshhead and the powder; the hogshhead was loaded with stones as deep as it could swim; a wooden pipe descending through the lower head of the hogshhead, & through the plank into the powder contained in the bottle, was primed with powder. A match put to the priming exploded the powder, which produced a very great effect, rending the plank into pieces, demolishing the hogshhead, and casting the stones and ruins of the hogshhead, with a body of water many feet into the air, to the astonishment of the spectators. This experiment was likewise made for the satisfaction of the Gentlemen abovementioned.

I afterwards made many experiments of a similar nature; some of them with large quantities of powder; they all produced very violent explosions, much more than sufficient for any purpose I had in view.

In the first essays with the submarine Vessel, I took care to prove its strength to sustain the great pressures of the incumbent water when sunk deep, before I trusted any person to descend much below the surface: and I never suffered any person to go under water without having a strong piece of rigging made fast to it, until I found him well acquainted with the operations necessary for his safety. After that I made

him descend and continue at particular depths, without rising or sinking, row by the compass, approach a Vessel, go under her, and fix the Woodscrew, mentioned in No 2, and marked A, into her Bottom, &c. until I thought him sufficiently expert to put my design into execution.

I found agreeably to my expectation, that it required many trials to make a person of common ingenuity, a skilful operator. The first I employed was very ingenious and made himself master of the business, but was taken sick in the campaign of 1776 at N.York, before he had an opportunity to make use of his skill, and never recovered his health sufficiently afterwards.

Experiments made with a submarine Vessel.

After various attempts to find an operator to my wish, I sent one, who appeared more expert than the rest, from N. York to a fifty gun Ship lying not far from Governour's Island. He went under the Ship and attempted to fix the Woodscrew into her bottom, but struck as he supposes, a bar of iron, which passes from the rudder hinge and is spiked under the Ship's quarter. Had he moved a few inches, which he might have done without rowing, I have no doubt, but he would have found wood, where he might have fixed the screw; or if the Ship were sheathed with copper, he might easily have pierced it: but, not being well skilled in the management of the Vessel, in attempting to move to another place, he lost the Ship. After seeking her in vain, for sometime, he rowed some distance, and rose to the surface of the water, but found daylight had advanced so far, that he durst not renew the attempt.

He says that he could easily have fastened the Magazine under the Stern of the Ship, above water, as he rowed up to the stern, and touched it, before he descended. Had he fastened it there, the explosion of one hundred and fifty pounds of powder, the quantity contained in the Magazine, must have been fatal to the Ship. In his return from the Ship to N. York, he passed near Governor's Island, and thought he was discovered by the Enemy, on the Island; being in hast to avoid the danger he feared, he cast off the magazine, as he imagined it retarded him, in the swell, which was very considerable. After the Magazine had

been cast off, one hour, the time the internal apparatus was set to run, it blew up with great violence.

Afterwards there were two attempts made in Hudson's River above the City, but they effected nothing. One of them was by the aforementioned person. In going toward the Ship, he lost sight of her, and went a great distance beyond her, before he found her; when he arrived, the tide ran so strong, that as he descended under water, for the Ship's bottom, it swept him away. Soon after this, the Enemy went up the river, and pursued the boat, which had the submarine Vessel on board, and sunk it, with their shot. After I recovered the Vessel, I found it impossible, at that time to prosecute the design any farther. I had been in a bad state of health from the beginning of

my undertaking, and was now very unwell; the situation of public affairs was such, that I despaired of obtaining the public attention, and the assistance necessary. I was unable to support myself, and the persons I must have employed, had I proceeded. Beside I found it absolutely necessary, that the operators should, acquire more skill in the management of the Vessel, before I could expect success; which would have taken up sometime, and made no small additional expence. I therefore gave over the pursuit, for that time, and waited for a more favourable opportunity, which never arrived.

Source: Thomas Jefferson Papers, Manuscript Division, Library of Congress.

Whiton, David Erskine (1825–1904)

David Erskine Whiton was an inventor and manufacturer. His name was familiar to machinists and craftsmen in the 19th century due to the popularity of machine tools bearing his name. In later years, the company he founded moved into the creation of steam turbines for naval vessels.

Whiton was born in Stafford, Connecticut, in 1825. After only a few years, Whiton left school, spending the rest of his youth as a carpenter's apprentice. He went west as a young man, settling briefly in Wisconsin before returning to Stafford. There, he opened a shop and went to work as a millwright. One of his most important products was a turbine-based waterwheel of his own design, but Whiton found his greatest success as a by-product of this business.

To accurately and quickly create turbine shafts, Whiton's shop relied on a centering machine that he'd created. It rapidly drilled and reamed steel shafts of various diameters, dramatically improving the productivity of machinists in many industries. In 1856, Whiton filed for a patent on his centering machine; the Whiton Centering Machine was soon found in machine shops across the country. Whiton received patents for several other machine tools and expanded his line of business into lathes and chucks—undramatic but essential tools in any machine shop. He also introduced improved gear-cutting machines. These devices

allowed machinists to quickly and accurately create gears to replace worn or damaged ones. Whiton's innovations improved the quality and speed of machining in countless small shops and large factories.

In 1886, the Whiton Machine Company moved to New London, Connecticut, to take advantage of the city's port and larger labor pool. While machine tools remained a vital part of his business, Whiton's expertise with turbines and the Whiton Company's new coastal location meant that he could become intimately involved in New London's thriving shipbuilding industry. Whiton centering machines were used to machine shafts for large naval turbines as well as for steam locomotives and later for automobiles and airplanes.

Whiton remained an active member of his community while running his business; he served in a number of elected positions. He served two terms as a state representative, representing his hometown of Stafford. Upon his death in 1904, he was succeeded as president of the Whiton Machine Company by his son, Lucius.

The Whiton Company long outlived its founder, remaining an independent company until 1970. It continues in operation today as part of Dresser-Rand, a division of the large German conglomerate Siemens. Its turbines power a large number of naval vessels, most notably the nuclear submarine fleet of the U.S. Navy.

James L. Erwin

See also *Vol. 1, Sec. 2*: Multitubular Boiler; Steam Engine; *Vol. 2, Sec. 1*: Iron Ship with Revolving Turret

Further Reading

J. H. Beers and Company. 1905. *Genealogical and Biographical Record of New London County, Connecticut*. Chicago: J. H. Beers.

Marshall, Benjamin Tinkham, ed. 1922. *A Modern History of New London County, Connecticut, Vol. II*. New York: Lewis Historical.

Winthrop, John (1714–1779)

John Winthrop, astronomer, physicist, and mathematician, was a fifth-generation descendant of Governor John Winthrop, founder of the Massachusetts Bay Colony. He served as Hollis Professor of Mathematics and Natural Philosophy at Harvard College from 1738 until his death in 1779. He was an accomplished scientist and preeminent American astronomer, whose observations on natural phenomena revolutionized colonial science and science education.

John Winthrop was born in Boston, Massachusetts, in 1714 to Judge Adam Winthrop and Anne Wainwright Winthrop. He entered Harvard at age 13 and graduated in 1732. He continued his studies and earned an AM in 1735. Once a professor at Harvard, Winthrop introduced his students to Newtonian principles of natural law. He created the first experimental physics laboratory in 1746, becoming the first professor to demonstrate the properties of electricity in a classroom, and he introduced elements of calculus to the Harvard curriculum in 1751. In 1746, he married Rebecca Townsend, with whom he had five sons.

Winthrop's cemented his reputation as America's foremost astronomer through the study of many astronomical phenomena. In 1740, he observed the transit of Mercury across the face of the sun, detailing the planet's movement. His findings, along with his observations on a lunar eclipse, were published in the Royal Society of London's *Philosophical Transactions*, the most prominent science journal of the time. He would publish 10 additional articles in the serial over the course of his career. In 1761, under orders from

Massachusetts Bay governor Francis Bernard, Winthrop led Harvard's first scientific expedition, a trip to St. John's in Newfoundland, Canada, to observe the rare transit of Venus. Despite swarming insects and threatening weather, Winthrop and two of his students made the only successful observations of the transit in North America.

Winthrop also had a great interest in natural phenomena. On November 18, 1775, he recorded detailed observations of an early-morning earthquake. In his account for the Royal Society of London, he correctly posited that earthquakes produce simultaneous horizontal and vertical movement, although he falsely asserted that earthquakes were caused by chemical explosions within the earth. His hypotheses placed him in opposition to prominent clergymen, including Boston minister Thomas Prince, who preached that earthquakes were manifestations of God's wrath. Winthrop published a second pamphlet, *Answer to Mr. Prince's Letter on Earthquakes*, in 1756 in response to Prince's claims. That same year, he married his second wife, Hannah Fayerweather Tolman.

Winthrop was elected a fellow of the Royal Society in 1766, thanks to support from Benjamin Franklin. He was named a fellow of the Harvard Corporation and received Harvard's first honorary LLD in 1774. He was active in public affairs, serving on the Massachusetts Bay Council in 1773–1774, and became a member of the Massachusetts Provincial Congress during the American Revolution. After the battles of Lexington and Concord on April 19, 1775, Winthrop rescued the college library and scientific instruments, moving them to Andover. He died in Cambridge, Massachusetts, on May 3, 1779.

Kathleen Barker

See also Franklin, Benjamin; Rittenhouse, David; *Vol. 1, Sec. 2*: Rush, Benjamin; *Vol. 1, Sec. 3*: Mitchell, Maria

Further Reading

Bernhard, Winfred E. A. 1990. "Brief Life of an Eminent Scientist: 1714–1779. Vita: John Winthrop." *Harvard Magazine* (September–October): 52.

Primary Document: John Winthrop Describes His Observation of the Planet Venus (1761)

Colonial Americans were fascinated by comets and by astronomy. Many astronomers began their studies looking for comets and discovered other astronomical phenomena. In the excerpt here, John Winthrop describes his 1761 observation of Venus at St. John's, Newfoundland. Winthrop would publish an account of his discoveries in the Philosophical Transactions of the Royal Society.

The town of St. John's being bounded with high mountains toward the Sun-rising, so that no house in it would answer our end, we were obliged to seek farther, and after a fatiguing and a fruitless attempt or two fix'd on an eminence at some distance, from whence we could have a view of the Sun presently after his rising. As this place was open and had no building near it, we pitch'd some tents upon it for a shelter, which, together with our Apparatus and such materials as we had occasion to make use of, we convey'd up thither with the labor of several days. We secured the Clock to a pillar set in the ground under a large tent. Near this tent and within call of the Clock we fix'd two others firmly in the ground: one, to mount the refracting telescope upon; the other, which was above 8 feet high, for a Style, having at top a plate of lead with a little hold for transmitting the

Sun's rays; and we laid a large horizontal Platform on the ground to receive these rays. This Platform we kept cover'd to defend it from the Sun and the weather, and examin'd its position every time we made use of it by a very long level. On this we carefully traced a meridian line, by correspondent altitudes of the Sun, taken both with the Reflector and by the Sun's image on the Platform. And, in order fully to examine and verify the meridian and adjust our clock, we repeated these operations every fair day, and many times in a day, and continued them with an assiduity which the infinite swarms of insects, that were in possession of the hill, were not able to abate, tho' they persecuted us severely and without intermission, both by day and by night, with their venomous stings. It would be tedious, as well as needless, to give a detail of the observations we made with this intent: 'Tis sufficient that we regulated the clock with as much exactness as we could have done at home. Thus prepared, we waited for the critical hour, which proved favorable to our wishes.

Source: Winthrop, John. 1761. *Relation of a Voyage from Boston to Newfoundland, for the Observation of the Transit of Venus, June 6, 1761*. Boston: Printed and sold by Edes and Gill, in Queen-Street.

2. The New Republic and the Market Economy (1780–1820)

OVERVIEW

Winning the Revolutionary War (1776–1781) jolted the American psyche. Farmers, craftspeople, and merchants had won independence from a ruling European monarch. The people of the United States of America had created a new country, but to join the global community of nations, they needed to invent their future.

Political freedom sowed national confidence; all things seemed possible. The nation's colonial past nurtured an innovative spirit, but disparate religious and political attitudes dismissed science. Before the country could build a future, attitudes toward science would need to evolve. An important step was establishing a strong foundation based on a factual understanding of the country's assets. The first national scientific effort was to collect population, economic, and geographical data.

Over the next 40 years, science and technology initiated major changes across the young nation; an agricultural colony dependent on imported manufactured goods transformed into a developing industrial powerhouse exporting products and ideas to the world. “Change” was the key word as America plunged into the market economy.

The Significance of American Immigration

Unintentionally, the colonial period created the perfect incubator for ingenuity. The distance between North America and its colonial rulers empowered colonists to prevail on their own. Without the controlling oversight of European craft guilds, knowledge was more freely exchanged, and immigrants from a range of countries and backgrounds contributed diverse skills and talents. Dutch sawmill design integrated with innovative English ironwork at the Saugus Iron

Works under Joseph Jencks (1599–c. 1682) to produce an American water-powered sawmill with 20 simultaneously running iron saw blades. German, Irish, and Scottish weaving methods combined with English looms to create American textiles.

African technologies for growing rice and producing pottery were assimilated into Southern plantation culture through enslaved Africans. Slaves, imported through the Caribbean, contributed knowledge of cultivating and processing indigo. Some enslaved individuals who had fought in the Revolutionary War were offered their freedom. Free people of color added their voices to the mix of ideas.

With the war's conclusion, many French, British, Scottish, and Hessian soldiers stayed to participate in America's opportunity. They brought European technological experience and helped invigorate the iron and mining industries. Immigrants to America frequently arrived with expertise in one trade, only to reinvent themselves in another. English weavers became farmers. Ironworkers became mechanics—designers of machinery. Benjamin Franklin (1706–1790) was a printer and author turned statesman and scientist. He learned fluidity of profession from his father, an English wool dyer who transformed himself into a soap and bayberry candle maker. In true American form, Charles Willson Peale (1741–1827) apprenticed in the leather trade, worked as a silversmith, and repaired clocks before becoming a successful portrait painter with the time and finances to explore his interests in natural history.

Political and Religious Attitudes toward Science

As early as 1743, the American Philosophical Society (APS) in Philadelphia, Pennsylvania, and activist

individuals like Franklin and Peale, had begun nurturing the seeds of scientific inquiry. But after a century of colonial existence, the infant country had little scientific or technological infrastructure. There were no schools of higher education in medicine, engineering, architecture, theoretical mathematics, or physical science. Americans lacked science education, but they approached problem solving with broad insight, varied experience, and flexibility.

Before the United States could embrace science and transformative technology, it had to address two philosophical hurdles: religious beliefs and political ideals.

Many early immigrants to the British colonies were religious refugees. Despite their own persecution in Europe, most groups established insular townships intolerant of other religious beliefs. Unifying Catholic Maryland, Puritan Massachusetts, Quaker Pennsylvania, Anglican Virginia, and Jewish communities in New York and South Carolina required a commitment to religious tolerance and freedom of worship. Unlike most European countries, which followed the religions and worldviews of their kings or queens, religious philosophy in the United States varied regionally.

In New England, Puritan Christianity impacted daily life, local government, and the first schools of higher education. Harvard College (founded in 1636; now Harvard University) and Yale College (founded 1701; now Yale University) were founded to train ministers and civic leaders. Eventually, these schools provided a rounded liberal arts education for the ideal gentleman, but even in 1780, this did not include physical science or theoretical math. Puritan “natural theology” supported identifying the general “laws of nature” to provide evidence of God as an intelligent creator. They believed that weather proved God’s informed manipulation of the environment; severe storms were God’s punishment. Such a worldview had limited use for scientific investigation.

Quaker religious philosophy emphasized a personal search for God in the physical world, a view that aligned with scientific inquiry. The Quakers believed that understanding nature could empower inventive individuals to improve life for everyone. Charting weather data enabled prediction of weather patterns, which could be published in almanacs to benefit

farmers and sailors. William Penn’s Quaker colony established the first fertile ground for science in the British colonies. Under Franklin’s leadership, the College of Philadelphia (founded 1756; now the University of Pennsylvania) was the first North American college to teach science in the form of natural history. With the exception of Pennsylvania’s, science in the colonies struggled and remained decades behind Europe’s.

Political beliefs also impacted science. In America, knowledge for its own sake had few champions. Most people spent their days producing for their daily needs or laboring to support themselves. A hardworking populace had proudly banished British aristocracy. In Europe, aristocrats and wealthy individuals pursued scientific endeavor at their leisure. Many Americans considered studying science undemocratic. Even the Quakers valued knowledge mainly for its practical uses. In a young America, college professors were expected to teach students, not waste time on research.

European governments or monarchs occasionally financed scientific inquiry, but the new American central government was too tenuous and underfunded. It would take 20 years and a president with a scientific background, Thomas Jefferson (1743–1826), before the U.S. government would financially support scientific investigation.

The Nation’s Foundation

American industry had been actively suppressed by Britain before the war. Most people, even the Founding Fathers, rarely traveled outside their home colony. Trade between colonies had been banned to maintain Britain’s monopoly on manufactured goods. Alexander Hamilton’s *Report on the Subject of Manufactures* (1791) revealed that most manufactured products in the new country were produced by resident craftspeople for local consumption.

Across all states, agriculture continued to be Americans’ dominant occupation. Most families produced food for themselves with marginal surpluses sold locally. In the South, a small but affluent agrarian society grew cash crops—tobacco, rice, indigo, and pine products—subsidized by the labor of enslaved African people. In 1780, as independent minds forged the new democratic government, they also collected practical

data on their new nation. The American Academy of Arts & Sciences (1780–) was established in Cambridge, Massachusetts, to support research and provide factual information to government policy makers.

Shipbuilding was the primary established industrial technology. Sailing ships or animal-drawn carriages provided most transportation. Wood supplied energy for cooking and heating. Small industrial enterprises, like sawmills or gristmills (processing grain), were powered by water, wind, or domestic animals on treadmills.

To determine the country's population, President George Washington (1732–1799) signed the 1790 Census Act. Much to his surprise, the census enumerated only 3.9 million people across the 13 states and four territories. The majority of citizens were of European descent or “white”; however, these individuals had come from a range of social backgrounds, religious views, and ethnic traditions. Fewer than 60,000 were free people of color. Over 694,000 individuals, or 18 percent of the population, were enslaved people, primarily from Africa.

While social and political change marked the early years of the United States, the success of the democratic experiment depended on economic transformation. An insular agrarian society dependent on imported manufactured goods needed to become a self-sufficient innovator and producer. The first step required was the public sharing of ideas. Incremental technological advances needed to be captured and built upon. During the Revolutionary War, Peale and astronomer David Rittenhouse (1732–1796) had worked together on a telescopic rifle sight. Ultimately, they were unsuccessful, and Peale only documented brief notes on their work in his diary. Throughout the colonies, individuals or workshops may have experimented with mechanical devices or scientific questions, but little was written down. Most innovators worked while ignorant of what others were creating. That was about to change.

Just as a committee had written the Constitution, dynamic technological growth in America occurred when many minds worked together or in competition. Scientific advances seldom bloomed in the hands of individual geniuses. The greatest American innovators were creative tinkerers who shared their successes and

failures and built on their discoveries. All citizens were asking: How could everyday life be made better? Science and technology were transforming all sectors of society: agriculture, industry, medicine, construction engineering, transportation, and energy.

Agricultural Innovation in the New Republic

Agriculture was initially reluctant to embrace new ideas. Land was fertile and abundant; farmers could produce enough to feed their families with reasonable surpluses. Change seemed unnecessary. Both Jefferson and Charles Newbold (1780–unknown) designed plows to increase agricultural efficiency, but neither was readily accepted. Farmers feared that Newbold's cast-iron plow would poison the soil.

Inventive farmers made slight plow modifications, but the motivation to increase crop production was not driven by farmers. Oliver Evans's (1755–1819) mechanized flour mill reduced the cost of producing flour and flour-based foods. To fill the growing consumer demand, farmers were propelled toward farm industrialization, mass-producing a single crop for sale.

As a young man, Oliver Evans (1755–1819) apprenticed in a wheelwright's workshop and often discussed ideas with his brothers. He combined gears and conveyor belts, turn-screws, and waterpower to design the first automated factory—a mill for grinding wheat kernels into flour. His automated mill functioned with minimal human supervision, greatly reducing manpower, and it tripled flour production. Eliminating human handling of wheat during processing reduced contamination and improved food safety.

Not only did Evans revolutionize flour production, to promote his design, he published his technical drawings in *The Young Millwright and Miller's Guide*. It became one of America's first accessible publications documenting a technological advance. Other inventive thinkers could examine Evans's ideas in detail. In 1790, when the federal government established the U.S. patent system, Evans's automated flour mill became American Patent No. 3. The U.S. patent system enabled creative men or women, of any ethnicity, to register an invention and legally protect their intellectual property. Technological advances and ideas were officially documented.

President Washington toured the countryside, visiting workshops and new enterprises, supporting and encouraging innovation. He was an early licenser of Evans's mill design. Invention was encouraged not only for individual financial gain, but also for the country's economic growth and entrance into world trade.

The Factory System

Industry initially took root in textile production. Samuel Slater (1768–1835) replicated British machinery to establish hydropowered yarn-spinning factories. Technology was pushing aside “homespun” fabrics created on spinning wheels and hand looms. Francis Cabot Lowell (1775–1817) and Paul Moody (1779–1831) grew the industry into all-inclusive textile mills. Raw fiber entered their factories and left as finished cloth. By 1814, powered looms were producing fabrics for clothing and bedding.

Ironworkers like David Wilkinson (1771–1852) recreated English textile machinery and evolved into mechanical engineers as they went on to develop their own inventions. The need for precisely machined, threaded parts inspired Wilkinson to create a sliding lathe to cut precision threading on metal screws, bolts, and instruments. The technology he created founded the American tool machinist industry.

Improvements in the cotton gin simplified and increased the processing of raw cotton. In the American South, slave labor subsidized production costs, making American cotton cheap. The growing availability of cotton fiber, combined with Hannah Wilkinson Slater's (1775–1812) patent for mechanically producing cotton thread (1793), ushered in cotton as a mass-produced textile. Technology made cotton a global product and transformed the American South's economy.

New technology also entered the home. Inventions like the apple parer, canned food, and the coffee percolator reduced daily work. Eli Terry's (1772–1852) mass-produced wooden clocks made desirable technology affordable for everyone.

The Challenge of Interchangeable Parts

The American iron industry was reborn in the market economy. The expertise to produce everyday ironware

had been lost over the generations of colonial ironworkers who had been pressured to supply minimally processed iron to England. In the years leading up to independence, American iron was shipped to England and forged into products and then resold to the colonists. After the war, regional foundries had to be reestablished, and skilled new immigrants reinvigorated the manufacture of iron products.

During the Revolutionary War, emergency production of cannon had occurred in small forges, but most firearms had been imported from France. In the first years of the new nation, armament manufacture became a priority. The American government's first investment in industrial research and development was to advance firearm production. Individual craftsmen producing individual guns could not deliver an adequate and reliable supply. American leaders sought to create the mass production of firearms. Achieving this technological leap required the development of precision manufacturing and interchangeable parts.

Jefferson had seen a demonstration of firearms composed of randomly selected individual pieces in France in 1785. “Interchangeable parts”—or finely produced integral pieces that could be substituted between the working elements in finished mechanical devices—became the holy grail of 19th-century manufacturing. Anyone who could successfully create interchangeable parts would forever change the production not only of guns, but all products with moveable elements—engines, clocks, sewing machines, etc.

While Eli Whitney (1765–1825) secured the first government contract to create firearms with interchangeable parts, most experts agree that he did not succeed. Thomas Blanchard (1788–1864) and John Hall (1781–1841) are the unsung heroes of American interchangeable-part technology.

In 1819 at the Springfield Armory in Massachusetts, Blanchard's workshop developed machinery with “tracer control.” A lathe cut an irregularly shaped gunstock by tracing the shape of an original item and replicating it. This innovation facilitated mass production of identical rifle stocks.

In the same year, the War Department contracted with Hall to produce 1,000 breech-loading rifles at the Harpers Ferry Armory in Virginia. By 1822, Hall and his crew successfully created interchangeable elements

between the working parts of rifles by using a “bearing point” reference. All measurements for the interworking parts were taken from this single reference point. Hall’s system assured that all of the mechanical parts could be precisely produced and uniformly fitted.

The U.S. government spent the equivalent of \$2 million on the development of interchangeable-part technology, but the investment had far-reaching consequences for American manufacturing. Blanchard’s tracer-controlled cutting enabled replication of an asymmetrical, contoured shape. The technology was used to mass-produce wooden axe handles and shoe-maker lasts. Later the concept was applied to shaping metal objects, including the common replication of keys. Hall’s method for producing precision interchangeable parts is used in every modern mass-produced automobile, airplane, electronic device, and machine—from toaster ovens to space satellites.

The Medical Sciences in Transition

Medicine was entering a period of transition. Since colonial times, most minor illnesses had been treated at home or with the aid of midwives like Martha Ballard (1735–1812). Prior to 1780, only two colonial colleges trained medical doctors: the College of Philadelphia and King’s College (which reopened after the Revolutionary War as Columbia College; now Columbia University). Harvard School of Medicine was founded in 1782, and by 1820, a growing faith in “science” placed greater confidence in college-trained male physicians.

Benjamin Rush (1745–1813), one of the foremost physicians in the young nation, personifies the transition between old methods and more science-based medicine. Rush continued the ancient practice of bleeding patients for all manner of sickness, but at the same time he led the movement to identify mental illness as a disease of the mind and not the consequence of evil spirits.

Benjamin Waterhouse’s (1754–1846) introduction of an English vaccination procedure for smallpox bolstered scientific medicine. Smallpox caused deadly epidemics in America. In 1800, Waterhouse approached President Jefferson with scientific data on smallpox immunity in people vaccinated with cowpox, a milder disease. Jefferson embraced the scientific evidence and

appointed Waterhouse to oversee a national vaccination program, the first American attempt to eliminate smallpox.

In the early 19th century, many people expected to lose their teeth by middle age. Dentist Levi Spear Parmly (1790–1859) theorized that tooth decay followed damage to the tooth’s external surface and that cleaning the teeth could prevent decay. He advanced oral hygiene by inventing dental floss.

Increased civic responsibility followed political independence and empowered citizens to improve public health. Under colonial rule, none of the large cities—Philadelphia, New York, Boston, or Baltimore—had had a municipal sewage system or public garbage collection. Sewage was dumped in the streets, and trash was piled at city outskirts. Springs, rivers, and wells, which provided drinking water, became heavily polluted. While the connection between disease and bacteria, or microbes, in drinking water was still unknown, the awful taste of city water caused concern. Civic leaders turned to inventors and new technologies to bring clean drinking water to city residents.

In 1799, Philadelphia installed the first steam-powered water pump to draw clean water from a distant reservoir into the city. Technology was now enabling cities to grow beyond local available resources.

Transportation Engineering

Construction engineering and transportation were directly impacted by independence from Britain. Prior to the war, each state had viewed itself as an insulated entity. Building was local and reflected the cultural background of the regional population. Math and engineering were not specific courses of college study. Travel was primarily by horseback, animal-drawn carriage, hand-propelled boat, or sailing ship. Road systems were minimal, and shipping lanes were often dangerous.

Mathematically talented individuals had few career paths: business accountant, ship navigator, or land surveyor. As a young seaman, Nathaniel Bowditch (1773–1838) taught himself complex mathematics to improve the safety of navigating ships along the New England coast. He created a manual that empowered even the least educated sailor to calculate a ship’s location.

First published in 1802, the *American Practical Navigator* transformed sailing safety and empowered ship crews. Captains and navigators could no longer tyrannically command crews of sailors ignorant of their location. Over 200 years after its publication, the manual continues to be revised and used around the world.

Bowditch further contributed to science in America by translating French works on theoretical mathematics and calculations on planetary movements. He provided the mathematical foundation for the study of astronomy in the United States and taught the first generation of American mathematicians.

As America entered the market economy, the need to move trade items transformed the countryside. Sailing ships had been the primary way to move goods from one colony to another, but they were limited to coastal port cities. Now, Presidents Washington and Jefferson lobbied for a national road to access the country's western interior. Where once temporary structures or ferries had crossed rivers, now individuals with vision were building sturdy bridges and planning canals.

In Europe, architects built bridges following ancient Roman arch design. Stone was the primary building material because wood was considered too precious. In America, lumber was the building material of choice; it was cheap and plentiful. Inventors like Ezekiel Reed (1772–c. 1852) and Jacob Perkins (1766–1849) were creating machinery to mass-produce nails. Self-taught construction engineers and architects experimented with novel ideas and built bridges to meet local community needs. Irish immigrant James Finley (1756–1828) patented the chain suspension bridge. Timothy Palmer (1751–1823) designed the first large-scale covered structure for the “Philadelphia Permanent Bridge.” Theodore Burr (1771–1822) developed the Burr arch truss, which supported the longest wooden expanse bridge in the world in 1804. These innovations changed bridge design and formed the foundation for modern steel-truss bridges.

Opening up the continent's interior for farming required transportation corridors through which agricultural products could be moved to ports and cities. In 1817, ground was broken on the Erie Canal. The dream was to connect New York City with the Great Lakes via the Hudson River. The Canal would stretch over 360 miles from Albany, on the Hudson River, to

the city of Buffalo, on Lake Erie, and form the largest inland canal system yet known to the world.

To raise a cargo ship 600 feet in elevation through a series of locks on a completely man-made waterway was deemed a superhuman feat. Yet, the men who achieved this engineering challenge learned on the job. James Geddes (1763–1838) and Benjamin Wright (1770–1842) were surveyors who taught themselves construction engineering. They assembled a team of individuals willing to experiment, fail, reevaluate, and succeed: Nathan Roberts (1776–1851), a farmer turned engineer, David Thomas (1776–1859), a botanist/surveyor/physician turned engineer, and Canvass White (1790–1834), the developer of a cement product that strengthened underwater.

As Americans were reshaping the countryside, the technology of their tools needed to evolve. Mechanician workshops, which had been the repairers of everyday items and builders of practical implements, became centers of machinery fabrication. Families involved with designing iron and wood fittings for mechanical devices ran regionally renowned workshops: the Jenckses and Wilkinsons of Pawtucket, Rhode Island; Simeon North's (1765–1852) metal milling shop in Connecticut, and Evans's “Mars Works” in Philadelphia. These hubs of innovation devised mechanical elements for drawbridges and canals, built industrial machinery, shaped metal for interchangeable parts, and developed engines to power the nation.

As men and animals moved boats along the Erie Canal, visionaries were experimenting with new forms of power. Robert Fulton (1765–1815) is credited with the first successful steam-powered boat, but his real contribution was marketing the technology. The steam engine evolved not from the work of one man, but from a list of competing pioneers: Wilkinson, John Fitch (1743–1798), working with immigrant mechanic Henry Voight (1738–1814); John Stevens (1749–1838); Captain Samuel Morey (1762–1843); James Rumsey (1743–1792); Thomas Paine (1737–1809); Nicholas Roosevelt (1767–1854); and Evans.

The Age of Steam

By 1814, Evans's high-pressure steam engines were powering city water systems, dredges, grain and

lumber mills, and iron and textile manufacturing, as well as watercraft. Roosevelt's steam-powered boat *New Orleans* navigated the fast-flowing Mississippi and Ohio Rivers in the newly acquired western lands. These rivers were too swift for hand-powered or sailing ships to effectively travel upstream. By 1820, 200 large steam-powered paddle-wheeled boats were opening up the Mississippi River basin to settlement, agriculture, and the establishment of large cities.

Energy for homes and even steam-powered engines would rely on wood for decades, but energy needs were changing. Initially, machine workshops and mills were located in small communities along swift-flowing rivers or streams. Hydropower was clean and renewable, but factories often discharged waste into rivers or diverted too much water, creating conflict with town residents. While hydropower remained the primary energy source until 1840, it suffered seasonal fluctuations or was disrupted completely during the winter by freezing. As cities of workers built up around industrial centers, waterpower became too contestable and unreliable.

Whale oil, used in lighting and lubricating machinery, was too costly to burn for power. To ignite the Industrial Revolution, factories needed reliable, year-round energy that could be employed away from waterways. In the coming age, corporate-funded science would transform alcohol-based fuel, anthracite coal, coal gas, and petroleum-based fuels into energy drivers.

Talented Amateurs

Pure science was difficult for practical Americans intent on building a new country to embrace. Physical sciences were only gradually integrated into America's higher education after the Revolutionary War. With the exception of Franklin, Rittenhouse, Rush, and a small number of educated physicians, most American science enthusiasts in 1780 were talented amateurs. The lack of science professionals, however, created opportunity for educated immigrants and determined underprivileged individuals.

Educated in France by one of the world's eminent chemists, Éleuthère Irénée du Pont (1771–1834) fled the French Revolution (1789–1799) and immigrated to the United States. He improved gunpowder refining

and in 1802 established one of America's first corporate chemical companies: DuPont. The War of 1812 (1812–1815) dramatically increased demand for gunpowder, and U.S. government contracts helped solidify DuPont as one of America's most profitable companies.

Freeborn African American Benjamin Banneker (1731–1806) established himself as a mathematician, surveyor, and astronomer despite little formal education. Several solar eclipses traveled across the United States between 1778 and 1806, thrusting astronomy into people's daily lives. Banneker accurately calculated the occurrence of a solar eclipse and became the first African American to publish an almanac. He used his mathematical expertise as evidence to directly challenge President Jefferson's belief that people of African heritage were intellectually inferior.

Thomas L. Jennings (1791–1859) became the first African American known to acquire a patent. Profits from his 1821 chemical dry-cleaning process enabled him to purchase his family out of slavery. Science and technology were providing new opportunities for people and changing daily life.

By 1800, the country was evolving in how it regarded the world and itself. The election of President Jefferson marked the second peaceful handover of governmental power—the union was stable. Americans could devote more time to recreational interests. As a natural history enthusiast and science aficionado, Jefferson championed the practical value of science and promoted scientific inquiry as a public passion.

Jefferson sent the Lewis and Clark Expedition (1804–1806) on the first U.S. government-financed scientific mission to map and explore the purchased Louisiana Territories. The explorers returned with natural history specimens, which enthralled the public and inspired a deeper interest in science.

In 1807, Jefferson established the U.S. Coast Survey—the country's first group of professional mathematicians and scientists. Most were students of Bowditch, and they accurately surveyed and mapped the nation's Atlantic Coast and newly acquired coastline along the Gulf of Mexico. They charted the Gulf Stream, investigated the magnetic force of the ocean, documented coastal marine life, and precisely determined longitudes using astronomical observation. The

Coast Survey remains one of America's oldest scientific institutions and in 1970 was incorporated into the newly established National Oceanic and Atmospheric Administration (NOAA).

As the country invested in science, the first generation of children born as U.S. citizens reached adulthood. The natural history movement founded by Franklin and nurtured by the APS and Peale's museum in Philadelphia encouraged public curiosity about the natural world.

Botany, biology, geology, astronomy, and natural phenomena were being taught in schools. The children of the market economy became America's first generation of science professionals: inventor Samuel Morse (1791–1872), botanist and chemist John Torrey (1796–1873), physicist Joseph Henry (1797–1878), and more.

The Fruits of Change

When Americans cast off their colonial ruler in 1781, they were forced to think, act, and provide for themselves. To meet their clothing, building, and food needs, Americans copied, improvised, innovated, and developed new technologies. By 1820, factory-produced textiles were leading the country toward the Industrial Revolution, and interchangeable-part technology was providing American manufacturing with an advantage over global competition.

Engineered roads, canals, bridges, steamboats, and public water systems were transforming the country physically and philosophically. Scientific knowledge was improving agriculture, industry, home life, medicine, construction, transportation, energy, and hopes for the future.

With the completion of the Erie Canal in 1825, Americans proved they could conquer nature and engineer projects beyond Europe's imagination. The Canal's success rippled through the American spirit. Canal engineers went on to execute more canals and roads, to design city waterworks, to plan the routes for the coming innovation—railroads—and even to influence the nation's first subway systems.

The Canal inspired the founding of the first U.S. technological research college, the Rensselaer Polytechnic Institute at Troy, New York. The Institute trained professional engineers such as Washington A.

Roebing (1837–1926), who designed the Brooklyn Bridge; Allen B. Du Mont (1901–1965), who developed television with the first practical cathode ray tube; Nancy DeLoye Fitzroy (1927–), an expert in heat transfer in space satellites; and John F. Schenck (1939–), a pioneer in magnetic resonance imaging (MRI) technology. In the 21st century, the legacy of the Erie Canal continues to educate technological visionaries.

Steam-powered shipping would evolve into steam-powered railroads. Bridge technology, developed to ford rivers, would span canyons and a continent. Technology would open up the heart of North America to mass migration.

Yet there was a dark side to America's technological growth. The engineering successes that challenged European industry and surmounted natural physical barriers bolstered the belief in "Manifest Destiny"—that Americans of Western European descent had been ordained by God to conquer the wilderness and the North American continent's native peoples. It supported the idea that one race had a God-given right to transform the land for its own purposes. Enslaving African peoples or displacing Native American cultures was deemed necessary for American advancement.

Growing populations and industrialization hungered for natural resources: agricultural land, lumber, iron, minerals, cheap cotton, abundant wheat, and new energy sources. Change was coming too fast for the social, environmental, and human costs to be fully appreciated. How would industrialization change families? How would city life affect people's relationship with nature? What impacts would technological advances have on the environment? Who would pay the consequences for unsustainable agricultural systems and unlimited harvesting of natural resources? Engineering advancements and technological innovations were driving the country forward, but not all of North America's residents would benefit, and the inequities would instigate war with Native peoples in the West and a Civil War over economics and human rights in the East.

From 1780 to 1820, America was a greenhouse for new ideas; 3,332 invention patents were registered with the U.S. Patent Office. Independence and a

diverse population created a country fertile with innovation. Most people benefited from improved daily life, health, and opportunity. Natural history was becoming a popular craze, inspiring public interest in botany and biology. Fields of scientific inquiry were growing and becoming professions. Some of the period's creative visions, however, were still dormant seeds—self-powered vehicles, controlled electricity, man-made refrigeration, and public sanitation. The technological and scientific seeds of change sown in the market economy would flourish and transform America.

Keri Dearborn

Further Reading

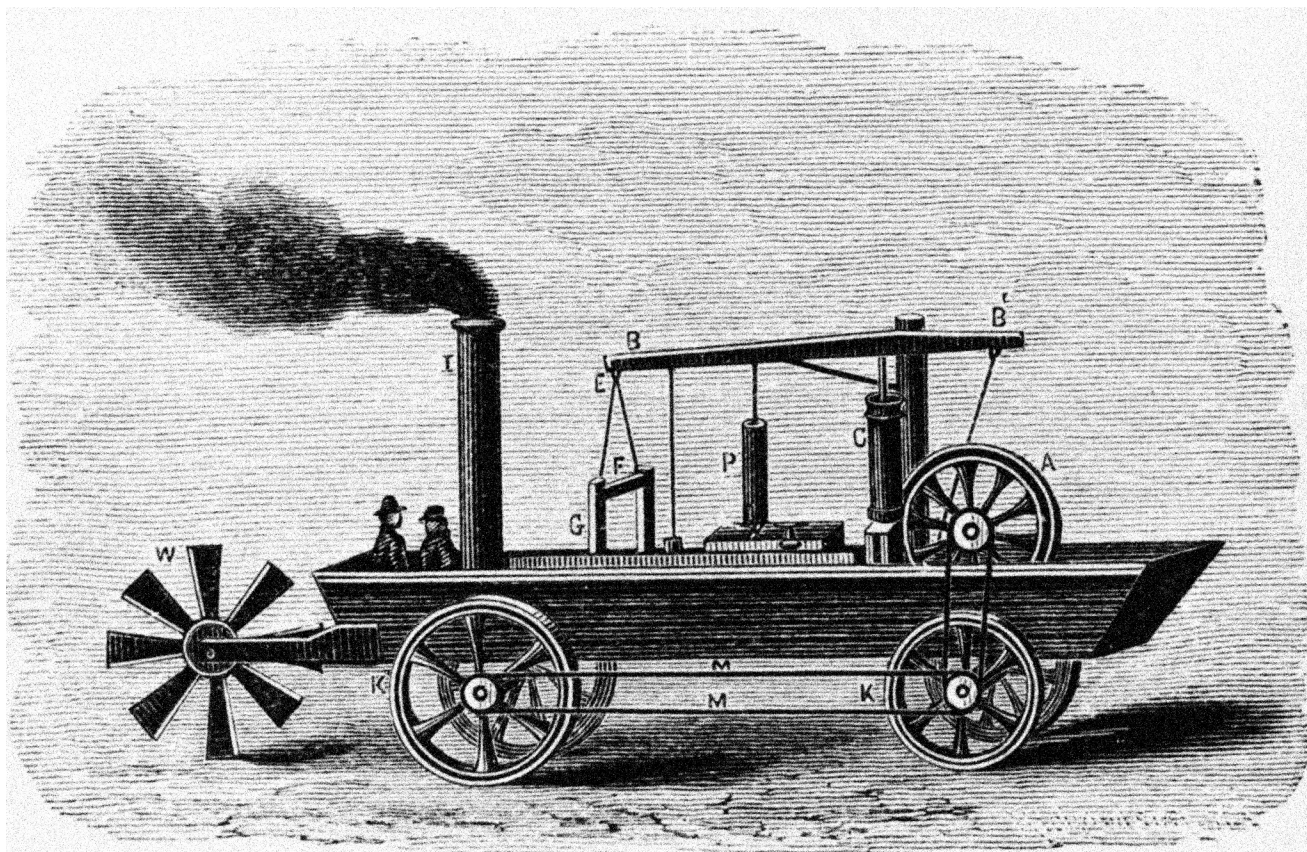
- Earle, Alice Morse. 1974. *Home Life in Colonial Days*. Stockbridge, MA: The Berkshire Travelers Press.
- Gies, Joseph, and Frances Gies. 1976. *The Ingenious Yankees*. New York: Thomas Y. Crowell.
- Grabiner, Judith V. 1977. "Mathematics in America: The First Hundred Years." In *The Bicentennial Tribute to American Mathematics, 1776–1976*, ed. Dalton Tarwater, 9–25. Washington, D.C.: Mathematical Association of America.
- Hawke, David Freeman. 1988. *Nuts and Bolts of the Past; A History of American Technology, 1776–1860*. New York: Harper & Row.
- James, Portia P. 1989. *The Real McCoy; African-American Invention and Innovation, 1619–1930*. Washington, D.C.: Smithsonian Institution Press.
- Jefferson, Thomas, U.S. Secretary of State. 1793. *Return of the Whole Number of Persons Within the Several Districts of the United States, According to "An Act Providing for the Enumeration of the Inhabitants of the United States;" Passed March The First, One Thousand Seven Hundred and Ninety-One*. Philadelphia: U.S. Government.
- Mandelker, Ira L. 1984. *Religion, Society, and Utopia in Nineteenth-Century America*. Amherst, MA: University of Massachusetts Press.
- Parslow, Virginia D. 1949. *Weaving and Dyeing Processes in Early New York*. Cooperstown, NY: The Farmer's Museum. http://www.cs.arizona.edu/patterns/weaving/monographs/pvd_ny.pdf, accessed August 23, 2018.

Amphibious Steam Vehicle

Known as the *Oruktor Amphibolos*, the first amphibious vehicle was built in 1805 by Oliver Evans, whose visionary designs made him an important figure in the American Industrial Revolution. Although the *Oruktor Amphibolos* was technically the first automobile in the United States and the first amphibious vehicle, it was never a commercial success.

Born in Newport, Delaware, to a farming family, Evans had little formal education. He was apprenticed to a wheelwright and learned wagon making as a teenager. By age 17, he was experimenting with ways of propelling wagons and carriages without animals. Fascinated by the possibilities of the steam engine, Evans applied for exclusive rights to build steam-powered carriages in Pennsylvania. He was unable, however, to generate enough financial backing to make a go of it. By 1802, he built the first high-pressure steam engine in the United States. High-pressure engines were smaller, lighter, and more efficient. Evans's engine was portable and could be used to power a wagon. Evans realized that the high-pressure steam engine would be crucial to the development of a steam carriage.

In 1804, after receiving a patent for his steam engine, Evans approached the city of Philadelphia about the possibility of designing a machine to clean the Philadelphia docks. He had no particular interest in dredges but was anxious for an opportunity to try his steam engine. The Philadelphia Board of Health commissioned Evans to build a steam-powered dredge for the city dockyards. The Board gave Evans a substantial advance, which he used up quickly without having anything to show for it. The Board got impatient when Evans failed to produce a vehicle. He was advanced more money, and in 1805, he finally finished the machine. The *Oruktor Amphibolos*—or "Amphibious Digger"—was a 30-foot 17-ton five horsepower high-pressure steam dredge. The flat-bottomed boat had a chain of buckets to scoop up mud, and the mechanism was driven by Evans's high-pressure steam engine. The engine was a grasshopper beam engine with an iron boiler mounted on bricks. The dredge was built in his workshop one and a half miles from the



Oliver Evans invented the Amphibious Steam Vehicle, or *Oruktor Amphibolos*, in 1804 in Philadelphia. (Hulton Archive/Getty Images)

Schuylkill River, where it would be launched. To move the dredge to the waterfront and also hoping to generate some publicity for his engines, Evans mounted the dredge on four wheels and connected them to the steam engine. The first wheels collapsed under the weight of the vehicle and had to be replaced. According to Evans, he ran the machine around the city square for several days and invited spectators to donate 25 cents each. He kept half of the money for himself to fund future inventions and gave half to his workmen, who he claimed had paid for the *Oruktor's* wheels. On the day of the launch, Evans drove the *Oruktor Amphibolos* from his workshop, through the streets of Philadelphia, and all the way to the waterfront, surrounded by crowds of curious onlookers. The engine was then connected to a paddle wheel, and the *Oruktor Amphibolos* steamed down the Schuylkill River to the Philadelphia harbor. As a dredge, it was ineffective, and the Philadelphia Board of Health sold it for scrap in 1808.

Although the *Oruktor Amphibolos* itself was more of a publicity stunt than a breakthrough in

steam-powered vehicles, Evans's engines were influential in the development of steam-powered automated industrial processes. He never built another steam-powered carriage or wagon after the *Oruktor*. Because Evans tended to exaggerate his accomplishments and there are few (and conflicting) contemporaneous accounts of the *Oruktor*, some people believe that the vehicle might never have made it to the Philadelphia dockyards. An account written in 1840 claims that Evans's underwater steam engine stood rusting on the streets of Philadelphia for months. Others claim that a five-horsepower engine could not have propelled a 17-ton dredge.

Kathleen Simonton

See also Steam Engine; Vol. 1, Sec. 1: Turtle Submarine

Further Reading

Bishop, J. Leander. 2009. *A History of American Manufacturers from 1608–1860*. Charleston, SC: BiblioLife.

Ferguson, Eugene, and the Hagley Museum Staff. 1980. *Oliver Evans: Inventive Genius of the American Industrial Revolution*. Wilmington, DE: Hagley Museum.

Klein, Maury. 2009. *The Power Makers: Steam, Electricity and the Men Who Invented Modern America*. New York: Bloomsbury, 2009.

Primary Document: Image of an Amphibious Steam Vehicle (1834)

This engraving of an amphibious steam-powered carriage and paddleboat designed by Oliver Evans appeared in the July 1834 issue of The Boston

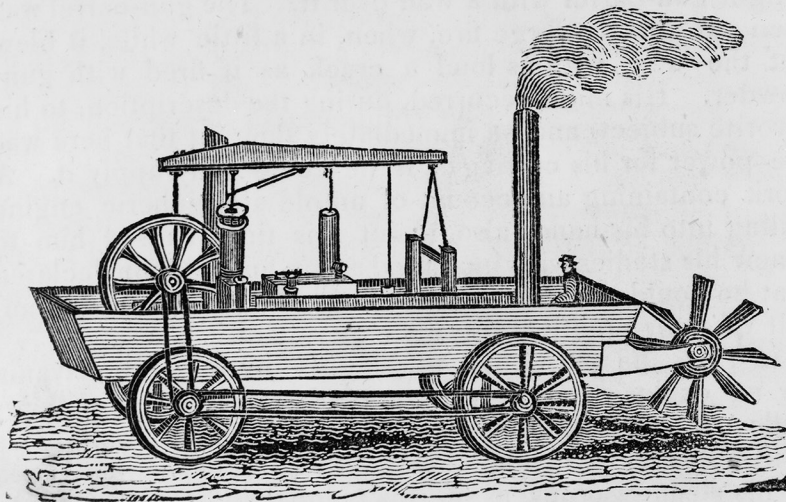
Mechanic and Journal of the Useful Arts and Sciences.

Source: Library of Congress.

The Mechanic.

JULY, 1834.

[For the Mechanic.]
STEAM-CARRIAGES.



[Evans' Steam-Engines. See page 196.]

HAVING traced the steam-engine from its first invention to the successful application of its power for the purpose of navigation, by Fulton, it now remains for us to continue the subject, by a brief history of its application to land-carriages on common roads, and its superior advantages on railways. Two individuals, in particular, are claimants for the honor of this invention, both of whom also claim the invention of steam-boats; but as all claims to the invention

Apple Parers

By the late 17th century, the apple was a popular fruit and a key agricultural product in the American colonies. The first apple orchard was planted in Massachusetts in 1635 by clergyman William Braxton, who had a farm in Boston's Beacon Hill. John Endicott, governor of the Massachusetts Bay Colony, planted the first nursery of apple and other fruit trees in America in 1640, while many believe that Peregrine White, the first child of the Pilgrims, planted an apple tree in Marshfield, Massachusetts, in 1648.

Apples were preserved as dried fruits and also made into applesauce, apple butter, and apple vinegar, all of which required paring and slicing, which were both difficult and time-consuming. After the harvest, early American communities held apple bees, where they socialized and pared apples. The November 1859 issue of *Harper's Weekly* reported that a popular pastime among marriageable girls during the bees was to divine the names of their future husbands by throwing the spirals of apple peel over their shoulders, looking at where the peels landed, and then trying to discern their future partners' names from the shapes of the peels on the ground. But given the drudgery of the peeling process with a handheld knife, the race was on to build an efficient mechanical tool for it.

Several individuals are credited for inventing the first apple parer. Eli Whitney, best known for inventing the cotton gin, is said to have invented one in 1778 at the age of 13. Locals in South Woodstock, Vermont, credit John Sterling for creating one in 1785. However, the official credit for the invention goes to Moses Coates of Downing's Field, Pennsylvania, who obtained the first patent for an apple parer on February 14, 1803.

The initial apple parers were handmade and primitive—they were made of wood and had a shaft with a crank on one end, and a wooden or metal fork to hold the apple in place at the other end. The crank had to be turned with one hand, with the other guiding the paring blade or knife that was mounted on a wooden handle. Types of early apple parers varied: there were straddle board, tabletop, table mount, floor pedestal, leg strap, knee hold, and bench types. As this tool evolved, the fork holding the apple was made to turn

faster by the addition of cords, belts, and gears. Yet the paring blade was still guided with the hand and was anchored to an upright post, just as in Moses Coates's invention.

Inventors during the early 19th century tried to outdo each other by creating superior versions of the parer to peel the apple as efficiently as possible. The first mechanical apple parer using a spring tension instead of the hand was created by Ephraim C. Pratt. His device left the operator with a free hand to remove the peeled apple and replace it with an unpeeled one. In his patent from October 4, 1853, Pratt claimed that his design allowed the knife to vibrate and match any irregularity in the surface of the apple or vegetable being pared. This instrument was made by Sargent & Foster's of Worcester, Massachusetts, and is considered the first cast-iron apple parer.

Subsequent inventors continued to improve this mechanical gadget. Apple parers of the late 19th century could be classified into four types based on their mechanisms: the lathe, the turntable, the arc (or geared segment), and the return (quick or otherwise).

As mass-produced food products became popular, the apple parer slowly disappeared from stores. Today, they are largely extinct, but not forgotten. They often show up at flea markets and antique shows, where collectors are willing to pay a lot to preserve a part of history with this fascinating tool.

Abhijit Roy

See also Whitney, Eli; *Vol. 1, Sec. 1*: "Saugus Pot"

Further Reading

- Barlow, Ronald S. 1992. *Victorian Housewares, Hardware & Kitchenware*. El Cajon, CA: Windmill.
- Franklin, Linda C. 1991. *300 Years of Kitchen Collectibles*. Florence, AL: Books Americana.
- Robinson, Charles L. 1946. "Apple Parers: An Aid to Inventive Progress." *The New York Historical Society Quarterly* XXX, no. 3 (July): 161–67.
- Thornton, Don. 2002. "Apple Parers: A Slice of American History." *Gastronomica: The Journal of Critical Food Studies* 2, no. 1 (Winter): 58–61.

Primary Document: Apple Parer Patent Document Image (1836)

The mechanical apple parer is a product of the Industrial Revolution in many ways. One of its less obvious connections is with the development of the Erie Canal, which allowed goods to be transported safely and affordably from the interior of the country to urban centers. With the canal, apples could be

moved in large quantities to early factories, where women used apple parers to quickly process large amounts of apples. The image below of an apple parer is from an 1836 patent document.

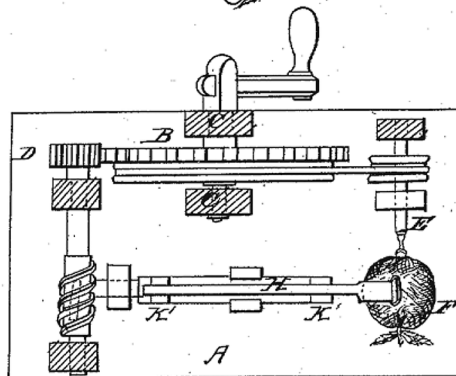
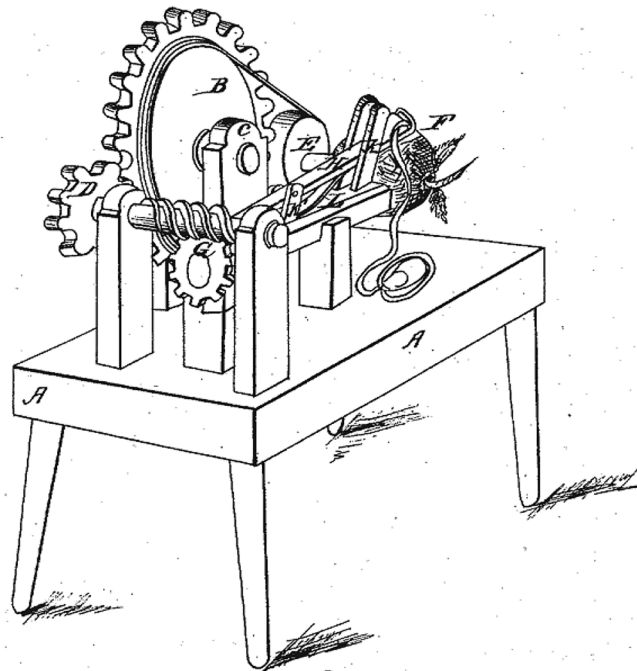
Source: United States Patent and Trademark Office.

9347X

J. W. Hatcher,

Apple-Parer,

Patented Feb. 3, 1836.



Babbitt, Sarah “Tabitha” (1779–1853)

Sarah “Tabitha” Babbitt was an American inventor and toolmaker, and she was a member of the Shaker community in Harvard, Massachusetts. She is credited with inventing the first circular saw used in a sawmill in 1813.

Babbitt was born in Hardwick, Massachusetts, to Seth and Elizabeth Babbitt. On August 12, 1793, she became a members of the Shakers, joining the community in Harvard. The Shakers’ name comes from their unique form of worship in which they express their joy through shaking, shouting, and dancing. Shakers practiced gender equality, adopted communal ownership of property, and emphasized simplicity in dress and architecture. They also adopted strict rules concerning celibacy, and new members came in the form of adult volunteers and the adoption of orphans.

According to Shaker history, Babbitt was working in the Harvard spinning house, watching men saw wood with a whipsaw, or pitsaw, which consisted of a narrow blade and a handle at both ends. The saw was generally operated by a two-man crew over a large pit on a sturdy platform. One person—the pit-man—would be stationed below the log, while the top-man would stand above or on top of the log. The teeth of the saw were angled and sharpened in the fashion of a ripsaw, designed to cut only on the downward stroke. Babbitt sought to rectify this inefficiency through the use of a round blade, or circular saw.

Unlike hand-operated saws, the circular saw is a power saw that uses a toothed blade to cut through materials with a constant rotary motion. The invention of this saw is commonly attributed to Samuel Miller of Southampton, England. He obtained a patent for a saw windmill in 1777. The form of the saw, though, was not well described, leading historians to believe that the circular blade was already in use and that it was the saw machine (rather than the blade itself) that Miller invented. Babbitt’s innovation was to harness the energy of water to power the circular saw in a sawmill. In 1810, she began experimenting with more efficient ways to cut lumber. Although few specific details of Babbitt’s saw have been preserved, her prototype likely consisted of a tin disk with notched edges for teeth. She mounted the disk to the spindle of her

spinning wheel, using the treadle, or foot pedal, to power the wheels and the spindle. This hand-driven model was soon extrapolated to create a larger, hydro-powered device for use in the Shakers’ sawmill.

The first recorded evidence suggesting Babbitt’s role in the invention of the circular saw appeared in a Shaker publication, the *Manifesto*, in February 1899. Although it is unlikely that she invented the device itself, Babbitt, and the Shakers, were likely among its earliest adopters and innovators.

Kathleen Barker

See also Ballard, Martha; *Vol. 1, Sec. 1*: Glover, Elizabeth; Lucas, Eliza; *Vol. 1, Sec. 3*: Crumpler, Rebecca

Further Reading

Miller, M. Stephen. 2010. *Inspired Innovations: A Celebration of Shaken Ingenuity*. Hanover, NH: University Press of New England.

Thurman, Suzanne. *O Sisters Ain’t You Happy?: Gender, Family, and Community among the Harvard and Shirley Shakers, 1781–1918*. Syracuse, NY: Syracuse University Press, 2001.

Ballard, Martha (1735–1812)

Martha Moore Ballard played a pivotal role in her community as a midwife and healer. Through her diary, she has become a historically important female voice documenting social, economic, and religious change in rural postcolonial America.

Few women could write in the 18th century, and fewer still participated in public life, resulting in poor documentation of women’s daily lives. Because women could not own property and seldom participated in legal matters, few details regarding individual women’s lives appear in historical documents. For example, the public record of Ballard’s life is limited to her birth sometime in 1735, her 1754 marriage to Ephraim Ballard, and their children’s birth dates. Ballard was a prominent figure in her community, yet, without her journal, the only thing we would know about her life would be a family story recounted by a famous grandniece, Clara Barton (1824–1912). Barton told the humorous tale of her grandmother and

great-aunt (Ballard) hiding in a cellar to brew tea in defiance of family support of the pre-Revolutionary tea boycott. The girls claimed that the tea was for a sick neighbor. Providing medical care ran in the family; Ballard's uncle and two brothers-in-law (including Barton's grandfather) were physicians.

Ballard spent the first half of her life in the town of Oxford, Massachusetts. At the onset of the Revolutionary War in 1777, Ballard and her husband relocated their family to a frontier settlement in Maine (then still part of Massachusetts). Hallowell was a remote community of approximately 100 families spread out along the Kennebec River.

On January 1, 1785, Ballard began writing daily entries in a hand-bound journal with a quill pen and ink. She was 50 years old, and for the next 27 years, she documented her daily work providing medical care, her financial transactions and movement through the community, the textile work of her daughters, and the interactions of everyday people. Combined with maps of the area created by her husband, a surveyor, Ballard's journal weaves a history of an American frontier community.

When Ballard began her journal, she had been an active midwife for seven years. Her neighbors sought her assistance because of her skills, experience, and knowledge as the mother of nine children. Her diary documents the delivery of 816 babies, including two of her own grandchildren on the same day. While childbirth could be quite dangerous, Ballard lost very few mothers and babies in delivery, a reality that signifies her midwifery skill.

Despite depictions of Puritans as prudish, Ballard's journal reveals tolerant attitudes toward premarital sex. Over 30 percent of children in the postcolonial Northeast were born out of wedlock. An unmarried woman who became pregnant sued the alleged father for financial support. Marriage might follow, but the community's concern focused on the child's financial well-being. If the couple did not marry but financial support was supplied, neither party incurred shame.

Ballard chronicles her bachelor son being accused of paternity. As a midwife, Ballard represented the community and questioned women at the height of labor to identify the child's father. The society believed that a woman could not lie at that precise moment, and childbirth statements were legally binding.

Ballard also nursed the sick and documented the community's medical history, including physical injuries and disease. Daily entries followed the arc of a 1787 epidemic; a single sick child evolved into a community plagued by scarlet fever and fatalities. Infectious diseases swept through colonial America; Ballard herself lost three young daughters to diphtheria in 1769. Communicable diseases caused catastrophic consequences when transmitted to Native American populations.

Attitudes toward medicine were also changing. Ballard's knowledge of anatomy and physiology came from experience. Male physicians were increasingly educated from books. Initially, two male physicians worked in Hallowell. Midwives treated minor illnesses and provided primary care to women and children. Most male doctors respected the midwives' expertise, and Ballard worked cooperatively with physicians. But in the later part of her career, young doctors were attending more births and pushing midwives out of the field. Ballard believed that some doctors recklessly prescribed opiate drugs to women in labor and endangered infants with the unnecessary use of forceps during delivery.

The increasingly male-dominated medical field demeaned midwifery as unscientific, but Ballard records rare statistical evidence supporting midwifery. Ballard lost five mothers out of 998 career deliveries. In comparison, London hospitals at the time reported the deaths of between 30 and 200 women per every 1000 deliveries. Ballard also recorded fewer stillbirths and neonatal deaths than her male counterparts. Some historians believe that the trend away from traditionally trained midwives and toward male physicians, considered to be more scientifically educated, negatively impacted women's health until the mid-20th century.

Midwifery was Ballard's occupation, and she tracked payment of birth "fees" or "rewards" (Ulrich 1990, 89) in a specific column in her daily entries. She was also compensated for herbal remedies—salves, syrups, teas, and pills. As she traveled through the community, Ballard detailed her economic interactions, including barter transactions between women, which are seldom historically documented.

The early years of the United States were economically unstable. Currency was unregulated and varied between states and regions. Dollars and cents replaced

English shillings and pence, yet Ballard frequently received shillings and other foreign currency in payment.

Physical paper money or coins were frequently unavailable. Ballard was compensated for one delivery with 18 pounds of butter, a dollar in currency, and three dollars paid toward her account at a store in town. Supplies were also borrowed or purchased on account. Ballard's record of economic transactions reveals an interdependent community network.

The diary also details Ballard's daughters' economic enterprise—weaving. Ballard knitted and mended family clothing, but she was often away from home several days a week. The family grew flax, raised sheep for wool, and owned a loom. All of the Ballard women spun yarn and thread, but the girls wove textiles. Weaving had been a man's occupation, but as the process became more automated, it provided less economic opportunity. Weaving gradually became part-time work for women in the late 18th and early 19th centuries. In families, homespun garments supplemented purchased manufactured clothing or fabrics. Women in the community specialized in different aspects of textile production and traded fibers or work. Ballard bartered a pair of leather shoes for 15 skeins of yarn. Another time, she traded flax to a seamstress who sewed dresses for the Ballard women.

The textile work documented in the journal chronicles a changing economy. The development of the cotton gin by Catharine Littlefield Greene and Eli Whitney in 1793 enabled mass processing of cotton and marked cotton's emergence as an important American textile fiber. Ballard notes purchasing raw cotton for processing into fabric. Within a generation, however, this opportunity for women disappeared as industrialization made home textile production unsustainable as a trade.

The postcolonial period brought religious questioning and evolving Christian sects: Free-Will Methodists, Shakers, etc. Religious instability fragmented the Hallowell community. Ballard documented a mass murder and suicide committed by a neighbor as a tragic incident, but men in the community blamed the murderer's religious beliefs for his actions.

Disagreements over religious doctrine caused a young minister to be driven out of town. He left his wife behind, and several prominent men in town

sexually assaulted her. Initially, Ballard wrote nothing specific in her diary about the event, but her visits to the young woman reveal that she became pregnant, and Ballard was aware of the situation prior to the woman coming forward publicly. Charges were brought against the town's influential judge, who was also Ephraim Ballard's employer. Court records did not record testimonies, but Ballard wrote out her statement in her diary. The victim had confided in the midwife. Ballard had encouraged the woman to remain silent. She felt that exposing the situation would be more detrimental to the young woman.

The penalty for rape was death in this period, but few men were found guilty. Puritan society regarded men as heads of households, with women beneath them. In most circumstances, a man's testimony was considered of greater value than a woman's. The rapist was acquitted, and Ballard lost confidence in the town's male religious leaders. Interestingly, after the trial, Ballard began referring to God as the "Great Parent of the Universe," a phrasing suggestive of her shifting religious beliefs.

Martha Ballard died in 1812 in Hollowell, Maine. Her family handed her diary down through the generations until her descendant Mary Hobart donated it to the Maine State Library in 1930. There it languished until historian Laurel Thatcher Ulrich began her work with it in the 1980s. In 1991, Ulrich's book based on the diary, *A Midwife's Tale*, won a number of prizes, culminating in a Pulitzer Prize. During a period of American history documented primarily from a male perspective, Ballard's diary offers a woman's point of view. She chronicled not only daily activities but also women interacting, creating an economic network, and participating in a culture that frequently overlooked their contribution.

Keri Dearborn

See also Greene, Catharine Littlefield

Further Reading

McCausland, Robert R., and Cynthia MacAlman
McCausland. 1992. *The Diary of Martha Ballard, 1785–1812*. Marco Island, FL: Picton Press.

Ulrich, Laurel Thatcher. 1990. *A Midwife's Tale: The Life of Martha Ballard Based on Her Diary 1785–1812*. New York: A. Knopf.

Banjo Clock

In 1802, Simon Willard patented and developed the banjo clock, also known as the patent timepiece. The internal movement of the banjo clock itself was designed to function as an eight-day timepiece using a pendulum 15 inches long. This meant that where most other clocks needed to be wound once a day, the banjo clock only needed to be wound once every week. Prior eight-day timepieces needed a movement of approximately six feet, by comparison, to function.

Famed clock maker Simon Willard was born in 1753 in Grafton, Massachusetts. He began studying horology (clock making) when he was 11 years old and established his first workshop in 1767. In 1780, Willard moved to Boston and set up a shop specializing in small clocks. In his lifetime, Willard manufactured over 4,000 shelf and wall clocks, including the revolutionary banjo clock and the “lighthouse clock.” The latter was the first alarm clock made in the United States.

Banjo clocks are gallery timepieces: wall-hung clocks that lack a striking mechanism, making them relatively silent. Three feet long or shorter, banjo clocks are typically characterized by having a painted dial, a long-waisted throat, and a square or rectangular pendulum box. This particular shape was responsible for the naming of the banjo clock—after the instrument it so closely resembled. The pendulum box was hinged for easy access to the weight and simplified winding.

Due to their small stature, sleek design, and mechanical improvements, banjo clocks became a staple of 19th-century life. Willard’s design became widespread and set the standard other clockmakers across the nation. This was enabled by Willard himself, as he permitted his relatives, apprentices, and associates to freely use his design. As such, many variations of the design developed. Alarm and hour-striking features were added to certain series, and grandiose versions were constructed to function at railroad stations throughout the country.

In 1801, Simon Willard was commissioned to construct a gallery clock for the U.S. Senate, which he personally constructed and installed. His time in the capitol resulted in a friendship with President Thomas Jefferson, from whom he received a silvered cane as a gift, and who later commissioned him to make one of

his patented improved timepieces for the University of Virginia. Later in life, Simon was invited to the home of former president James Madison, where he was gifted a second silvered cane in recognition of his work. Two of Simon Willard’s final works were commissioned in the capitol: the first was a meticulously designed banjo clock for the Supreme Court Chamber, and the second was a custom mechanism fitted to the statue *The Car of History*, which resided in the House of Representatives.

Reed K. Wilkinson

See also Interchangeable Parts; *Vol. 1, Sec. 1*: Three-Wheel Clock

Further Reading

Bruton, E. 2004. *The History of Clocks & Watches*. Edison, NJ: Chartwell Books.

Willard, J. W. 1962. *A History of Simon Willard, Inventor and Clockmaker*. Mamaroneck, NY: Appel.

Blackwell, Elizabeth (1821–1910)

Elizabeth Blackwell was the first American woman to receive a medical degree. She helped establish the first medical training schools for women in the United States and England. Blackwell faced many obstacles, but in her determination, she became a trailblazing reformer.

Blackwell was born in Bristol, England, in 1821 (becoming a U.S. citizen in 1849). In 1832, the Blackwell family, which included nine children, moved to the United States. In England, her father Samuel had been a part-time preacher who spoke out against all forms of oppression. In America, he supported abolitionist and temperance causes. Samuel died in 1838, leaving the family destitute. To make a living, the Blackwell family opened a private school. However, the venture failed, and Blackwell took jobs in North Carolina and South Carolina teaching music to girls. She felt unfulfilled, though, because she wanted to make a greater difference in the world. Although her father was gone, his spirit for reform resonated with her.

In 1845, Blackwell found her calling when she visited a dying friend who explained to Blackwell that



The first woman to receive a medical degree in the United States, Elizabeth Blackwell founded the New York Infirmary for Indigent Women and Children in 1853 and later worked with Dorothea Dix to train nurses for the Union effort during the Civil War. (Hulton Archive/Getty Images)

she would have sought treatment for her uterine cancer sooner had women doctors been available to her. Due to the morality norms of society in antebellum America, many women opted to suffer with gynecological ailments in silence rather than to seek medical attention from male doctors. In keeping with these norms, male medical students were often instructed to dim the lights during childbirth and other similar procedures to keep the woman's modesty intact. These practices were detrimental to the health of women. Blackwell became convinced that women needed women doctors. While boarding with a medical doctor's family, she borrowed medical books and independently studied to prepare herself for medical school.

In a male-dominated society, her dream was certainly difficult to achieve. She applied to but was rejected by 29 medical schools on account of her sex.

Finally, in 1847, she was admitted to the Geneva University Medical School in upstate New York. Geneva was in no way more progressive than other schools; the faculty had turned the decision over to the male medical students, who had voted to admit Blackwell because they believed she would surely fail and in this way, they could teach her a lesson. Indeed, the circumstances of her admittance set the tone for her tenure at the school, where she was often ostracized and marginalized. In spite of these and other obstacles, she successfully completed her studies in 1849. However, once graduated, she found it impossible to find work as a doctor. Hospitals would not hire a female doctor. She also found it difficult to rent lodgings, because many people viewed a female doctor as an immoral or reprehensible kind of woman.

Blackwell went to Paris, where she was also denied hospital employment. Consequently, she began working in clinics for the poor, dealing with various female- and child-related health issues. In Paris, Blackwell witnessed male doctors' mistreatment of female patients, which strengthened her conviction. Unfortunately, her plan to become a surgeon vanished when she contracted an eye infection. She lost one of her eyes and ended up with diminished sight in the other. In 1858, she met Florence Nightingale, who tried unsuccessfully to convince Blackwell that nursing was the best place for women in the medical field. After more training in England, Blackwell returned to the United States right before the outbreak of the American Civil War (1861–1865).

Due to Blackwell's poor eyesight, she used her medical expertise in an administrative capacity only. During the war, she helped create the Women's Central Relief Association (WCRS) to train nurses who served as volunteers aboard hospital ships as army nurses and as relief workers. After the war, Blackwell and her sister Emily, who also became a doctor and faced similar obstacles, established the Women's Medical College—the first women's medical training school in the United States. The Blackwells' school trained more than 300 women doctors. Having eschewed marriage, Blackwell adopted a young child in 1869. The same year, she returned to England, where she remained until her death in 1910. She helped establish the London School of Medicine, the

first women’s medical school in England, where she taught gynecology.

Rolando Avila

See also Vol. 1, Sec. 3: Dix, Dorothea; Hospital Transport Service, Women’s Department; Nightingale Plan

Further Reading

Boyd, Julia. 2005. *The Excellent Doctor Blackwell: The Life of the First Female Physician*. Stroud, UK: Sutton.

Wilson, Dorothy Clarke. 1970. *Lone Woman: The Story of Elizabeth Blackwell, the First Woman Doctor*. Boston: Little, Brown.

Primary Document: Excerpts from “Address on the Medical Education of Women” by Elizabeth and Emily Blackwell (1863)

In 1863, Elizabeth Blackwell and Emily Blackwell, both medical doctors, addressed a meeting of the New York Infirmary with a speech on the importance of medical education for women. Elizabeth Blackwell faced considerable resistance to her mission both to open medical education to women and to provide medical services to poor women and children. The following is an excerpt of her address.

ADDRESS
ON THE
MEDICAL EDUCATION OF WOMEN,
PREPARED BY
DRS. E. AND E. BLACKWELL,
READ BEFORE A MEETING HELD AT THE
NEW YORK INFIRMARY,
DECEMBER 19TH, 1863.

ADDRESS

The present meeting has been called to consider the subject of organising a Medical College for Women.

I shall take it for granted, therefore, that those present approve of the study of Medicine by Women—either upon the general ground of widening their occupations—or from the feeling that in special departments of medicine, there would be an obvious advantage in being able to consult women—or that they would be valuable as teachers to diffuse sound hygienic knowledge.

There is one other point, however, on which I should like to touch—it is the question of educating good nurses. It has been frequently said to us, “If you would establish a school for nurses,—or if you would make nursing a prominent part in your medical school, it would appeal more forcibly to the public.

Now, we fully acknowledge the need that exists of a good school for nurses. The Infirmary was chartered as a practical school for nurses as well as students; and it has given similar advantages to nurses, in their department, that it has to students—viz., the opportunity of learning, by taking part in practice. In this way it has trained a succession of nurses, who are now employed in New York.

This is a matter on which we have had a good deal of experience. We were engaged in the effort made by the Woman’s Central Relief Association at the beginning of the war, to provide nurses for the first military hospitals. Several of our students also have been engaged in these hospitals. Moreover, we are well informed of the results of Miss Nightingale’s efforts, both before and since her labors in the Crimea. The result of our experience has been to strengthen our long-entertained conviction, that there must be women physicians to raise up the class of nurses the public require. It is the doctor who must train the nurse; and we have found that men, with the best intentions, find it very difficult to adapt themselves to their instruction; and moreover, that though feeling strongly the necessity, they do not take the same interest in instructing nurses that they do in teaching students. We feel, therefore, that it would be a much easier and more practicable thing to organize good instruction for nurses, after we have formed a medical school, and have drawn together intelligent women, students and assistants, than to form the school for nurses with the hope that the medical school would follow. In fact, we need the higher class to educate the lower, and without them it seems to us impossible to accomplish the work satisfactorily.

We wish it, therefore, to be distinctly understood that a radical improvement in the character and

training of nurses, in private service and in connection with public charities, will be the direct result of a superior class of educated women being engaged in medical service—that is of Women Physicians.

Let us then take up the main question, and that we may realize that the practice of medicine by women is a growing influence, and cannot be overlooked, allow me to state a few facts drawn from personal experience.

In 1845 when I resolved to become a physician, six eminent physicians, in different parts of the country were written to, for advice. They all united in dissuading me, stating, “That it was an utter impossibility for a woman to obtain a medical education; that the idea though good in itself, was eccentric and utopian, utterly impracticable!” It was only by long-continued searching through all the colleges of the country, that one was at last found willing to grant admission. When I entered college in 1847, the ladies of the town pronounced the undertaking crazy, or worse, and declared they would die rather than employ a woman as a physician. In 1852, when establishing myself in New York there was the utmost difficulty in finding a boarding-house where the simple name, as physician could be placed; ladies would not reside in a house so marked, and expressed the utmost astonishment that it should be allowed in a respectable establishment. I presented American and foreign testimonials of medical qualification, to one of the city Dispensaries, asking admission as assistant physician, in the department of diseases of women and children; the request was refused. I asked permission to visit in the female wards of one of the city hospitals; the application was laid on the table, not being considered worthy even of notice. There was a blank wall of social and professional antagonism, facing the woman physician, that formed a situation of singular and painful loneliness, leaving her without support, respect, or professional counsel.

Now these few facts taken from individual experience, are fair illustrations of the general feeling of society, and the attitude of the profession towards women physicians in 1852.

Let us see what facts present themselves to justify the assertion, that this new idea is now firmly rooted:

First,—As to the recognition of the propriety of women studying medicine. Since then ten male

medical schools have received women as students, and given them the diploma of Doctor. In three states, female medical schools have been established, holding charters granted by the State legislatures; the diploma conferred by them placing their graduates on exactly the same legal footing, as the ordinary physician; the corporators of these female colleges being respectable bodies of men and women, and in some instances enlisting the sanction, by subscription, of a very large number of influential citizens. From the most accurate data, which we have been able to collect, several hundred women have been graduated as physicians at these schools within the last ten years. At five different times, women have been admitted (as exceptions) to our large New-York hospitals to follow the visits of physicians as students, the medical faculties having given their consent in these cases. One of the largest dispensaries in the city, has during the last six years, allowed a little group of respectable female students to continue their daily attendance. The school of Pharmacy has also opened its doors to women as students. No respectable woman practitioner has now any difficulty in holding medical consultation with some of the men most skilled in the various departments of medicine.

Now all will agree that pecuniary success is a very convincing thing! We may deplore the low state of society, which will measure truth by dollars; but nevertheless we cannot shut our eyes to the fact, that the mass of mankind do judge by a low standard. To say, such and such a woman is making \$2000 a year by the practice of medicine, creates more respect for the work in the minds of most people, than any amount of argument, or abstract statement of the truth and value of the idea, would do. We can use then this poor, powerful argument of the dollar. We can point out women in Boston, New York, Philadelphia, Cleveland, and elsewhere, personally known to us who are making more than \$1000 or \$2000 a year, in a steadily increasing practice; all grown up within ten years!

Several things are proved by this fact. It shows that women can practise medicine in some fashion—they have the head to do it;—that there is nothing in the work itself, to hinder them from doing so—they have the health to do it—; it shows that women will employ them; that imperfect as their education is (as we shall presently see), and with the distinct knowledge on

the part of women, that these physicians have not the advantages of education which men enjoy, they nevertheless employ them widely and increasingly.

I think these facts will be considered as establishing the statement that the practice of medicine by women, is no longer a doubtful, but a settled thing; that a new social power is growing up in our midst, concerning which the question is—not shall it exist, but how shall it exist—shall its influence be for good or for harm? It needs but a moment's consideration to see how very deplorable the influence of an ignorant class of female physicians must be!

We believe that the time has come to form a really good school of medicine for women. The hospital organization, under the title of the N. Y. Infirmary for Women and Children, has been preparing the way for such a school for nearly ten years, and its working has been watched by the profession even more than by the community during that time. Many of the best men of the medical profession in New York are now prepared to encourage the formation of a medical school for women, in connexion with it. The Trustees of the Infirmary entered into negotiations this spring with the leading medical colleges of New York, to obtain their counsel in this matter. The subject was carefully considered by them; and the result was an expression of friendly interest in the object, with a recommendation to pursue our present plan of action.

We have thus two important elements to start with: an institution of several years' standing, whose directors, whose aims, whose manner of working are already known and approved of; and the friendly confidence of an influential portion of the profession.

Two other things are now wanted, in order to establish a college: money, which men so liberally give; social influence, which women can so effectually exert.

We need such an endowment as will enable us to secure the assistance of first-rate professors, and to commence such a system of education as I have described—thorough, and practical in its character.

It is also necessary that such a body of ladies as well as gentlemen shall join with the Trustees of the Infirmary, as corporators of the College, as will assure the public and the profession, that this effort possesses the sympathy and support of the women of New York.

In appealing to our fellow-citizens for support, or in asking the profession for their aid, it is justly a first consideration with them—is this effort endorsed by the women of our city!

The question has been asked us repeatedly by business men and by physicians.—Can you show that women want this thing done? We know that this question can be answered in the affirmative; we know that there is a wide-spread interest felt by women in this work, and we earnestly appeal to them to prove the truth of this statement by taking part in this effort.

In conclusion we ask all who feel that this is a good work that ought to be accomplished, to realize that it rests with them to assure its success, by an open and decided support.

Source: Blackwell, Elizabeth and Emily Blackwell. 1864. *Address on the Medical Education of Women*. New York: Baptist and Taylor.

Burr Truss Bridge

The Burr truss bridge (also called the Burr arch truss bridge) was invented in 1804 by Theodore Burr, a saw-mill owner from Torrington, Connecticut. He patented his bridge design as a special combination of an arch and a multiple-kingpost truss in 1817. The strength and stability of the bridge structure was increased by adding an arch to the kingpost truss and hence, for the first time, American bridge builders were able to build a wooden truss bridge with spans over 100 feet.

The first Burr truss bridge was built at Waterford, New York, in 1804. It was built over the Hudson River in four spans with a total length of 800 feet but was destroyed by fire in 1909. Also in New York, the longest single span (228 foot) wooden bridge over Schoharie Creek, the Blenheim Bridge, was another superb example of the Burr truss bridge. It was opened to the public in 1855 and survived until 2011, when flooding from Tropical Storm Irene washed it away. Many Burr truss bridges were built successfully in Pennsylvania, New York, and neighboring states.

A timber truss had been used for centuries for building bridges. A great Italian architect of the Renaissance period, Andrea Palladio, described the mechanism of a truss in his Treatise *I quattro libri dell'architettura* (1570). Early American bridge builders used wooden trusses for a few reasons. First, timber was abundant in the United States, and it was a lightweight and inexpensive construction material in comparison with stone and iron. Second, the unique triangular design of a truss, offering both tensile and compressive strength, provided flexibility to the bridge designers. Timber bridges were made of different types of trusses as developed by different bridge builders, such as the plank-lattice truss, the kingpost truss, the queenpost truss, etc. All of those timber bridges were covered by a roof and siding (thus also called covered bridges) to protect structural members from weather.

At that time, there were also many massive arch bridges made of stonemasonry, and hence they were labor-intensive and expensive alternatives to wooden truss bridges. However, the masonry arch bridges provided greater stability under moving loads compared to the wooden bridges, and that was the major difference between these two types of bridges. The moving load is a small part of the total load for a masonry arch bridge, since its dead load is massive. The weight in the spandrels keeps the arch from distorting under a moving load, so it does not fail by buckling. However, a moving load is the greater part of the total load for a lightweight wooden truss bridge. The arch is likely to fail by buckling when the moving load is applied only on part of the bridge.

Theodore Burr understood the load distribution mechanism better than other designers of his time and added a stiffening truss to the arch to prevent buckling. His design proved quite successful, and a great many bridges were built following his design principle. Burr himself supervised the building of five bridges crossing the Susquehanna River—four in Pennsylvania and one in Maryland—between 1811 and 1818.

The Burr truss bridge is best classified as an auxiliary arch system. The timber trusses in his design consisted of parallel chords tied together by vertical posts and stiffened by crossed braces. Each segment of the timber arch was fitted into the next by lap joints and was also attached on both sides of the posts and braces.

The segments were through-bolted to the vertical posts, sandwiching the truss. The ends of the arches were connected to the abutments below the bed timbers.

The design principle behind the Burr arch truss was that the arch should be capable of bearing the entire load on the bridge while the trusses were used to stiffen the arch for a moving load. Although the kingpost truss members were capable of carrying the load, it was difficult to calculate the load-sharing of a moving load crossing the bridge between the arch and the truss members.

Later computer models were used to analyze the load distribution of these bridges, and it was found that the truss members bore the majority of the loads while the arch provided the stability. In any case, the combination of the arch and the truss provided a more stable bridge capable of supporting greater weight than either the arch or truss alone.

Most of the Burr truss bridges were destroyed or replaced later by steel trusses. One of the refurbished Burr arch trusses is Historic Hall's Mill Bridge in Hopewell Township of Bedford, Pennsylvania. It was built in 1860, reconstructed in 1884, and refurbished over the years.

Mousumi Roy

See also Suspension Bridge; *Vol. 1, Sec. 3*: Brown Truss; Howe Truss; *Vol. 2, Sec. 1*: Brooklyn Bridge; Steel Arched Bridge

Further Reading

- Haupt, H. 1851. *Theory and Practice of Bridge Construction*. New York: D. Appleton.
- Melbourne, C., ed. 1997. *Arch Bridges*. London: Thomas Telford Services.
- Nelson, Joseph C. 1997. *Spanning Time: Vermont's Covered Bridges*. Shelburne, VT: New England Press.
- Trautwine, J. C. 1888. *The Civil Engineer's Pocket Book*. 13th ed. New York: John Wiley and Sons.

Canals

Canals are human-made channels for water. The term can be applied to those that are used for irrigation as well as for generating power, but for the most part,

canals are man-made waterways used to transport goods and people on canal boats. With waterways essentially being America's "superhighways" in the early 19th century, canals were the engineering marvels that played a vital part in the growth of the nation as well as spurring technological innovation that took America to the next level of both transportation and prosperity.

With the canal system, America's distant frontier communities could be connected with the bustling commerce of the eastern seaboard. Canal boats were inexpensive transport for west-bound immigrants and other settlers along with the manufactured goods they would need. Eastbound, canals were the conduit for raw materials such as the coal, grain, lumber, and stone that fueled the Industrial Revolution.

At their most basic level, canals are trenches filled with water. Depending on the terrain, it is sometimes necessary to line a canal with watertight material such as clay or concrete. Ideally, the canal can be filled easily with water, as in the case of those open to a river or the sea. Where the canal is not at sea level, water might be pumped or otherwise carried from nearby rivers or reservoirs.

Canals also need to be level. Cuttings and embankments can be used to correct small height differences in the terrain, but for larger deviations, other approaches such as locks must be engineered. Along the side of the canal, there must be land called a "towpath" for horses, mules, or humans to tow the boats floating down the canal. Early barges could be propelled manually by pushing a pike and using a rudder while proceeding downstream, although horses on the towpath would still be needed to haul the boats upstream. Later, barges could be motorized, though they tended to be larger and used for canals with deeper drafts. During their heyday in the 19th century, canals in America were usually about 60 feet wide and five feet deep.

Canal boats can carry many times the weight that can be hauled by a human or animals pulling a cart. Canals are not subject to rutted, obstructed, or mud-filled roads. The boats can be easily guided as they float down the canal. While a horse could carry one-eighth of a ton, a canal barge could carry 30 tons. Canals were the engineering and economic marvels of their age.

Though it is technically a "millrace" carrying water to a waterwheel and built for industrial purposes,

the oldest known canal in America was Mother Brook. Also known as Mill Brook, it ran between the neighborhoods of Dedham and Hyde Park in Boston, Massachusetts. It was constructed in 1639 to provide waterpower for mills, connecting the Charles River with the mouth of the Neponset River and the sea.

However, it was the Industrial Revolution in the 18th and 19th centuries that truly initiated the age of the modern canal system. With the coming of the Industrial Revolution, there had to be an economical and reliable way to transport large quantities of raw materials and finished goods. In 1761, the Duke of Bridgewater opened the first successful major British canal. The Duke, who owned a number of coal mines in northern England, wanted an inexpensive, reliable way to transport his coal to the industrial city of Manchester. He financed the Bridgewater Canal himself and found it to be enormously successful. The boats were horse-drawn, with a towpath alongside the canal. This system proved to be highly economical and became standard for canals both in Britain and beyond. America took note.

Lacking dukes with deep pockets, canal companies in the United States were initially chartered by individual states. Canals were seen as vital to improve inland transportation in North America, which at the time was limited to trails and coastal navigation. Canals were constructed, owned, and operated by private joint-stock companies that collected tolls for use of the waterways. By 1812, three were completed and open for business: the Santee Canal in South Carolina (opened in 1800), the Middlesex Canal in Massachusetts (1802), and Virginia's Dismal Swamp Canal (1805).

Mountain ranges often limited the inland reach of canals to a few hundred miles, with river navigation frequently blocked by rapids or waterfalls. Segments between navigable waterways involved a portage where freight was carried by horses. With more advanced engineering innovation, locks were constructed on the canals that allowed a much more efficient means of transport by raising and lowering the water level. In the early 19th century, two American canal systems emerged—one east of the Appalachians near the East Coast and one west of the Appalachians in the Midwest.

The eastern canal system connected coastal cities to sites as far inland as possible. The second, in the Great Lakes region of the Midwest, linked the Ohio River to Lake Erie, enabling access to the region's agricultural resources and carrying them back to the East Coast. Two of the most important canals were the Ohio & Erie Canal (completed in 1833) connecting Akron, Ohio, with the Cuyahoga River, and the Wabash & Erie Canal (1853) linking Toledo, Ohio, on Lake Erie to Evansville, Indiana, on the Ohio River. As the country moved westward, the 96-mile Illinois and Michigan Canal (completed in 1848) ran between Chicago and the Illinois River, becoming an important factor in the subsequent role of Chicago in becoming an important transportation hub in North America.

For several decades in the early 19th century, Ohio and Indiana built many miles of canals. However, it was two eastern canals that especially captured the nation's imagination. The Erie Canal (opened in 1825) was chartered and owned by the state of New York and financed by bonds bought by private investors. Running almost 400 miles, it connected Albany on the Hudson River to Buffalo on Lake Erie. With its numerous locks, the Erie Canal was considered the engineering marvel that opened the West to settlement. It unleashed the growth of the United States, as well as making New York City, at the mouth of the Hudson, the nation's center of finance and commerce. Soon after its 1825 opening, the Erie Canal proved commercially successful through its use of tolls, quickly paying back its investors and earning a substantial profit; construction began on an enlargement just 11 years later. Cities, towns, businesses, and industries mushroomed along the Erie Canal's route in upstate New York.

With the opening of the Erie Canal and its access to the Hudson River, there was an all-water route from the Great Lakes to the port of New York City and the Atlantic Ocean. The canal cut transportation costs in half, allowing the inexpensive transport of agricultural products grown in the Great Lakes region to the rest of the world.

The profits generated by the Erie Canal prompted a canal-building boom in the United States that peaked about 1850, when railroads began competing in price

and convenience. But in its heyday, the Erie Canal was a technological landmark. It reached into remote areas, bringing isolated people on subsistence farms in touch with the world beyond. With access to available markets, new settlers joined them by the score. The Midwest, via the Erie Canal, especially offered viable options for new immigrants (many of whom had been farm workers) beyond the teeming cities of the East Coast.

The other well-known waterway in the 19th century was the Chesapeake and Ohio Canal that linked Cumberland, Maryland, with Washington, D.C. Usually abbreviated as the C&O Canal and occasionally called the "Grand Old Ditch," it operated near the Potomac River from 1831 until its abandonment in 1924. When the C&O Canal was opened in 1850, reports noted that on its first day of business, five canal boats, loaded with a total of almost 500 tons of coal, came down from Cumberland. The C&O carried more coal on that first day than the Lehigh Canal had done for its full first year of business in 1820. Yet in 1850, the C&O Canal was already facing competition from the Baltimore and Ohio (B&O) railway. The C&O's company dropped plans to extend the canal into the Ohio Valley. But the C&O still hung on as a viable means of transport until the mid-1870s, when improved rail technology, such as air brakes and larger steam locomotives, allowed the railroad to set rates lower than could the canal, sealing the waterway's fate. In 1938, the abandoned canal was obtained by the U.S. government and is now the Chesapeake and Ohio Canal National Historic Park, a beloved recreational feature for residents of the nation's capital.

By the latter part of the 19th century the great majority of America's canals were abandoned as they lost their commercial edge to railroads. Many had limited draft, which restricted their load-bearing weight and required high upkeep, and so they were financially unable to compete with railways. Those that remain today, such as the Erie Canal and the C&O, are used for recreational purposes and are managed by state or federal governments as parks. Portions of some canals have been restored by historical groups for cultural and recreational purposes.

Ironically, the heyday of canals also led to their demise. The first small rail lines were constructed for

portage between canal segments. One of the first rail lines to be established in the United States, the Philadelphia and Columbia Railroad, was built in 1834 to complement the Schuylkill and Union canals between Harrisburg and Philadelphia, Pennsylvania. That same year, the Allegheny Portage Railroad became the first railroad constructed through the Allegheny Mountains, as it linked the Pennsylvania canal towns of Hollidaysburg and Johnstown.

Early canal enthusiasts included both Benjamin Franklin and George Washington, who believed canals were the key to America's future. For a time, they were right.

Nancy Hendricks

See also Flatboat; Steam Engine; *Vol. 1, Sec. 3: Railroads*

Further Reading

Shaw, Ronald E. 1993. *Canals for a Nation: The Canal Era in the United States, 1790–1860*. Lexington: University Press of Kentucky.

Sheriff, Carol. 1997. *The Artificial River: The Erie Canal and the Paradox of Progress, 1817–1862*. New York: Hill and Wang.

Wright, Kevin W. 2016. *The Morris Canal and the Age of Ingenuity: Climbing Mountains to Solve America's First Energy Crisis*. Charleston, SC: America Through Time.

Canning Factory

Robert Ayars established the first American canning factory in New York City in 1812. The process of preserving foods within airtight containers had first been implemented by the French military in 1810, during the Napoleonic Wars. Within a year, the technology had advanced from airtight glass containers to tin cans. The factory constructed by Robert Ayars industrialized the production of tin-plated, wrought-iron cans and expanded the number of foods that could be preserved by canning.

The definition of canning itself is the preservation of perishable goods by killing microbes through pasteurization, boiling, freezing, or treatment with microbial

agents before sealing them within airtight containers. Foods preserved in this way could have dietary supplements added to their contents, including vitamins, sodium, and fiber. Canning is such an effective method of food preservation that canned goods taken off a boat that sank in 1865 were still safe to eat in 1974.

Food preservation techniques prior to canning (such as salting, smoking, and pickling) were very time-consuming and risked spoilage if the process was performed incorrectly at any intermediate stage. In addition, after the food was preserved, exposure to the elements would spoil the preserved food unless kept in an airtight container.

The sturdy design of Ayars's cans and the speed with which they could be packed resulted in a steady method of supplying sanitary and appealing food to people across the nation. Foods sold through Ayars's canning business quickly became popular with citizens throughout the eastern states and were a quick favorite of military personnel, who once regularly suffered severe starvation and food spoilage. By 1812, fruits, vegetables, meats, and oysters were all popular canned goods, particularly among the working classes. Canned foods also allowed urban populations, who did not live near sources of fresh food, to eat a variety of foods more safely. Canning factories sprang up across the nation to meet the demand, including Underwood, famous primarily for canned meat spreads.

Demand for American canned goods increased rapidly during the Civil War (1861–1865), particularly after the War Department discovered that canned food like meat was much less likely to go bad and make soldiers sick. German American Henry Heinz founded one of the nation's largest canning companies in 1869, promising consumers products that were safe and pure. Heinz got his start in canned horseradish in part because other brands used sawdust as filler.

The process of canning, both in wrought-iron tin cans and glass jars quickly became common across the entirety of the United States, as it allowed homesteads and individual families to preserve foodstuffs produced on their own lands and stave off hunger and malnutrition. By the late 19th century, companies competed in canning luxury and novelty foods. Can labels also became increasingly colorful and artistic in nature.

William Lyman invented a rotating can opener in 1870 that made opening cans significantly more convenient for consumers. In 1888, Max Ams pioneered the double-seamed tin can, a more airtight version than earlier cans.

Many ventures into the west of North America were successful due to the preserved food supplied by Robert Ayars's factory and others that had quickly risen in a rejuvenated preserved foods industry. The advancements of technology had significantly increased the distance that people could reliably travel without concern for food.

However, canning factories have historically been sites of worker abuse. Factory work is often seasonal and low wage. Factory workers, particularly immigrants, are vulnerable to unsafe conditions, low pay, and long hours. Some of the nation's most vigorous labor organization has come from these factory workers, including the United Canning, Agricultural, Packing and Allied Workers of America (UCAPAWA), which was formed in 1937 to protect food processing workers.

The cultural aftereffects of the advancements in canning are still felt today, as preservation of agricultural goods throughout the seasons has led to the expectation that most foods can be commercially purchased during any time of year, with extended freshness. It also meant that for the first time, perishable goods could be transported across the Atlantic Ocean, enabling foreign nations to consume agricultural goods from the United States, and vice versa. For many people, this was the first and most elementary form of intercultural experience—foods from a foreign land and not native to their own.

Reed K. Wilkinson

See also *Vol. 2, Sec. 1: Can Opener*

Further Reading

- Jeanroy, A., and K. W. Jeanroy. 2009. *Canning and Preserving for Dummies*. 2nd ed. Indianapolis: Wiley.
- Ruiz, Vicki. 1987. *Cannery Women, Cannery Lives: Mexican Women, Unionization and the California Food Processing Industry, 1930–1950*. Albuquerque: University of New Mexico Press.

Charting the Gulf Stream

Benjamin Franklin created the most efficient way of charting the Gulf Stream in the North Atlantic Ocean with his cousin Timothy Folger and published their findings in England in 1769. Their original Franklin-Folger map of the gulf stream measures 38.5 inches by 34.5 inches and was superimposed on a map based on observations made by the famous astronomer Sir Edmond Halley, who had correctly predicted the appearance of the comet that bears his name.

Franklin made eight voyages across the Western Ocean (as the Atlantic Ocean was known at that time) between the Colonies and Europe. He observed that journeys eastward from the colonies to Europe were faster than return trips. Franklin was interested in this phenomenon as deputy postmaster of the colonies. While in England in 1768, he had heard complaints from the Colonial Board of Customs about British packet ships carrying mail that took several weeks longer to reach New York from London than average merchant ships to reach Newport, Rhode Island, from Falmouth, Cornwall.

Franklin posed the question to his cousin Timothy Folger, a Nantucket whaler and ship captain, who explained to him that merchant ships and mail packet captains traditionally tried to avoid strong eastbound mid-ocean adverse currents of up to three miles per hour. They worked with other experienced ship captains, learning enough to map the gulf stream along the North Atlantic Drift, which originates in the Gulf of Mexico, exits through the Strait of Florida, and follows the eastern coastlines of the United States and Newfoundland before crossing the Atlantic Ocean.

Franklin named the current the Gulf Stream, as it is still known today. Franklin and Folger also added notes on how to avoid the stream and adjacent shoals when traveling westward. The map was completely ignored in England when Franklin had it published by British cartographers John Mount and Thomas Page in 1770 and gave to British sailors. Perhaps the British packet captains ignored it out of arrogance and refused to admit that colonial fisherman knew more about the ocean than the superiorly trained and experienced British mariners. Perhaps they were also annoyed

because of the colonies and Franklin's opposition to the Stamp Act of 1765, which had forced the colonists to buy a British stamp for every official document they obtained.

After the commencement of the American Revolution, Franklin ceased distributing the chart to the British to prevent their fleet from having the competitive advantage of such valuable information. Subsequent versions of this map were printed in France in 1778 and in the United States in 1786. It took several decades for British sea captains to adopt Franklin's advice on navigating the current, and they were ultimately able to cut their sailing time by about two weeks. In 1853, oceanographer Matthew Fontaine Maury noted that the existence of the Gulf Stream had been known to Peter Martyr d'Anghiera and Sir Humphrey Gilbert in the 16th century, even though Franklin and Folger were the first to codify the nautical account.

In March 1775, Franklin left London and sailed for Philadelphia. The following year, in December 1776, he was sent to Paris as an envoy of the United States to negotiate a treaty with the French government. During those two transatlantic crossings, he tested the temperature of the Gulf Stream and learned that it was warmer than the surrounding waters. He incorporated these findings into the Franklin-Folger chart and had it copied and printed by Parisian cartographer Georges-Louis Le Rouge following his arrival in Paris. He provided copies of this map to all French ship captains carrying arms and supplies to the American colonies.

In 1786, after the end of Revolutionary War, Franklin published his and Folger's sketch of the Gulf Stream as part of an article in the *Proceedings of the American Philosophical Society of Philadelphia*.

The original Franklin and Folger charts disappeared and were assumed lost for almost two centuries until September 1978, when Philip L. Richardson of the Woods Hole Oceanographic Institution discovered two copies in the Bibliothèque Nationale in Paris. This finding was reported in the front pages of the *New York Times* and *Science* magazine in 1980. Since the mid-20th century, more sophisticated maps of the Gulf Stream have been charted. When the Franklin-Folger chart is compared with these charts derived from sensitive infrared photographs taken from satellites, it is

remarkable how accurately the 1769 chart depicts the path of the great river in the ocean.

Abhijit Roy

See also *Vol. 1, Sec. 1*: American Philosophical Society; Franklin, Benjamin

Further Reading

- Bache, Franklin. 1936. "Where Is Franklin's First Chart of the Gulf Stream?" *Proceedings of the American Philosophical Society*: 731–41.
- Pillsbury, John Elliott. 1891. *The Gulf Stream: Methods of the Investigation and Results of the Research*. No. 10. Washington, D.C.: U.S. Coast and Geodetic Survey.
- Stommel, Henry M. 1958. *The Gulf Stream: A Physical and Dynamical Description*. Berkeley: University of California Press.

Circular Saw

The circular saw is a power saw involving an abrasive disk or blade that cuts materials with a rotary motion. Its inventor is not clear. Some credit Tabitha Babbitt, an American Shaker and an inventor who was the first to affix a circular saw in a sawmill in 1813. As that story goes, she observed local timbermen sawing logs using a pit saw that had two handles and was pulled from side to side. The saw only cut the wood when it was being pulled forward; the reverse pull only served to bring it back to the starting position. Babbitt came up with a new saw designed to utilize energy the whole time that it was in motion. She created a prototype by attaching a circular blade to her spinning wheel and using the pedal to power it.

Others claim that such a saw had appeared in a different Shaker community a few years earlier. What is known is that Shakers did not patent their inventions. Instead, the circular saw was patented in the United States in 1816 by two Frenchmen who read about the saw in Shaker newspapers. Still others say that such a saw existed in Europe as early as 1777. Either way, the saw revolutionized the work of tradesmen around the world.

Rosanne Welch

See also Babbitt, Sarah “Tabitha”; *Vol. 2, Sec. 1: Pipe Wrench*

Further Reading

Simonds Manufacturing Company. 2017. *Circular Saw: A Guide Book for Filers, Sawyers and Woodworkers*. London: Forgotten Books.

Coffee Percolator

The coffee percolator was invented by the renowned American-British scientist Sir Benjamin Thompson, aka Count Rumford. Thompson’s design, intended to promote sobriety, became the basis of later percolators, which remained largely unchanged in basic



A coffee percolator cycles boiling water through the grounds using gravity until the required strength is reached. The Aluminum Company of America produced this model in 1932. The electric drip coffee maker replaced percolators in the early 1970s. (Indianapolis Museum of Art/Getty Images)

design for well over a century until the widespread use of the drip coffee maker in the 1970s.

The preparation of coffee had been slowly refined for centuries. Coffee beans were roasted and ground, and then most drinkers simply poured the grounds into boiling water and poured it out once the coffee had brewed, using narrow-waisted pots to capture the grounds. Early drip pots were in use by the end of the 18th century, but the taste of the coffee was affected by the cloth filter that these pots used. An improved version of the drip pot, the first modern percolator, was invented in 1800 by the French Bishop Jean-Baptiste de Belloy. This device was further refined by Count Rumford.

Rumford, born Benjamin Thompson, was an American-born Loyalist who fled America to Britain. He was well known as a researcher, administrator, and inventor and was knighted by King George III. In 1786, with the permission of British authorities, he moved to Bavaria and assumed a series of high government positions there. He was made a nobleman and chose the name Count Rumford. One of Rumford’s obsessions was the promotion of sobriety, and to that end, he created an improved version of de Belloy’s percolator in 1810.

Modern percolators are used to heat water on a stove; the hot water rises through a small tube onto coffee grounds and then drips down into the main chamber of the percolator, to be poured out once the coffee has finished brewing. De Belloy and Rumford’s designs were much simpler, and Rumford’s design added a sleeve of insulating water. By surrounding the coffee with hot water, the coffee could be kept hot for a long period. This was an important consideration for soldiers and workmen who wanted a warm beverage without the inconvenience of a fire. In his capacity as an advisor to the Bavarian king, Rumford promoted his percolator to the Bavarian military, and it caught on quickly.

Rumford’s design spread across Europe and the United States. As coffee continued to grow in popularity, many inventors refined the percolator. In 1865, James Nason of Massachusetts patented the first modern two-chamber percolator. In 1889, Hanson Goodrich of Illinois patented a design very similar to modern stovetop percolators. While electric coffee makers have eclipsed percolators in popularity in recent decades, many consumers still use percolators

in their homes, and larger percolators remain a popular way to serve large quantities of coffee at meetings or events.

James L. Erwin

See also Rumford Fireplace; Thompson, Benjamin (Count Rumford)

Further Reading

Bramah, Edward, and Joan Bramah. 2002. *Coffee Makers: 300 Years of Art and Design*. Shrewsbury, UK: Quiller Press.

Pendergrast, Mark. 2010. *Uncommon Grounds: The History of Coffee and How It Transformed Our World*. New York: Basic Books.

Cotton Gin

Eli Whitney's cotton gin is one of the most impactful inventions in American history. First unveiled in 1793, the cotton gin not only altered the young nation's economy, it also changed the nature of the American labor force, for in making the process of separating the cotton from the stem easier, the gin created a greater demand for slaves to pick the cotton. Given the limited market and the challenges central to effectively and profitably growing and harvesting cotton, the slave labor force in the United States had, in fact, been diminishing when Whitney created his machine. However, the increased profitability that the cotton gin inspired created an increased demand for slave labor. The end result of Whitney's invention was an increase in the importance of slavery to the American economy, an increase in its presence in the American South, and thus an increased commitment to keeping alive a practice that would ultimately be at the center of the events that led to the Civil War and which continue, in their own way, to impact daily life in the United States to this day. Yet ironically, for all its national impact, for Whitney himself, the invention was more trial than triumph, with legal battles based in disputes over patent rights costing him most of what he might have made. In frustration, he turned his creative energies to other projects, with the development of interchangeable parts being his biggest other legacy.

Whitney invented the cotton gin in the early 1790s. He first applied for a patent in October 1793 by sending a drawing of his creation to the Department of State, which administered the granting of patents. While the idea was approved, for a patent to be issued, a model had to accompany the request. Consequently, Whitney spent the next six months constructing one. Finally, on March 14, 1794, following a demonstration in the secretary of state's office in Philadelphia, Whitney was issued his patent.

The machine had had its origins in Whitney's visit to the Georgia plantation of Catharine Littlefield Greene, the widow of the Revolutionary War general Nathanael Greene. Whitney had intended to read the law and help the plantation manager, Mrs. Greene's fiancé, Phineas Miller, a fellow Yale alumnus, in whatever way he could, but upon arriving at the plantation, it took the analytical Whitney just a short time to recognize the labor problem inherent in the process of extracting fiber from cotton by hand. Indeed, the process of separating the prized cotton lint from the seed by hand was tedious and painful. One hand had to hold the seed while the other sought to tease out the useful lint. By most accounts, it took an individual 10 hours to separate one pint of cotton lint from three pounds of the harvested cotton. Ever the tinkerer, Whitney quickly set about the task of developing a machine that would make the process easier and more efficient.

The machine Whitney designed to undertake this arduous task was, in fact, a comparatively simple mechanism. Indeed, that was part of the reason that it was so easily pirated later. In Whitney's creation, the hand that held the seed was replaced with a kind of sieve of wires that were stretched out lengthwise. In his early efforts, making the proper wire was a bigger challenge than stretching it out because the ideal kind of wire did not exist. However, that problem was ultimately solved. Meanwhile, the next step was to design a means whereby the lint would be extracted. To replace the human fingers that performed the task of literally pulling out the lint, Whitney had a drum rotate past the sieve, not quite touching it. Attached to, but projecting out from, the drum's surface, were fine, hooked wires that caught at the lint. Secure behind the sieve, the seeds were restrained while the lint was pulled away. The final piece was a rotating brush that

spun four times faster than the drum, and thus it cleaned the lint off the hooks.

In an early demonstration before friends, Whitney's machine accomplished in one hour what would have been a full day's work for several workers. Not surprisingly, the gin's early demonstrations were met with an immediate and positive response. Indeed, from a business perspective, the cotton gin's popularity was its own undoing. So popular was the gin and so great was its impact that before Whitney had even completed the formal model required to obtain final patent approval, versions of the gin were already in operation on farms and plantations throughout the region. As a result, despite the patent, Whitney and Miller saw little substantive profit—certainly nothing approaching what they had hoped and rightfully anticipated. Indeed, despite a series of legal battles, the machine was pirated, copied, and used all over the South, to the distress and frustration of Whitney and Miller.

From the outset, Whitney and Miller had planned to lease their cotton gins, taking a percentage of their profits as their compensation. However, with no precedent for such arrangements, they had difficulty establishing an appropriate percentage rate, and farmers, desperate to use the revolutionary machine, were not willing to wait while Whitney and Miller worked through the business complications. Meanwhile, the two entrepreneurs, having used their resources to design and make the machine, were desperate for income and the funds needed for the ongoing struggle to establish their legal rights, a problem compounded by the fact that most of the courts in which they sought to establish their claims were in the midst of cotton country and not very sympathetic to their plight. In fact, the primary legal fight over the patents for the cotton gin was ultimately settled in 1807 after about 60 different lawsuits. But while Whitney was established as the inventor of the cotton gin and he would collect \$90,000 from the legal effort, the time and money involved in the lengthy process meant that in the end, neither he nor Miller achieved any significant financial reward.

But the business machinations surrounding the origins and early operation of the cotton gin did nothing to limit its widespread use or dampen its historic impact. Indeed, for all of the difficulties and problems

Whitney and Miller may have had, the impact of the gin on American cotton production—its amount and its method—was extraordinary. Indeed, coming at a time when new power looms in both New England and Europe could turn the cotton into cloth at previously unimagined rates, the impact of the cotton gin, both directly and indirectly, was immediately clear—and only increased.

In fact, whereas in 1791, the United States produced 2 million pounds of cotton fiber, by 1801, it had increased to 48 million; and by 1830, the country was producing half of the world's supply. That figure would rise to 1.65 billion pounds by 1860, a figure that represented two-thirds of the world's total, while also easily making cotton the nation's largest export. Quite simply, the cotton gin revolutionized cotton production in the United States, and at the same time, it changed the human dynamic involved with harvesting the crop, creating a greater demand for the labor needed to pick the newly grown cotton. In fact, the increase in cotton production was mirrored by an increase in slave labor. In 1790, the number of slaves living in the United States was just under 700,000. The number grew to a little under 900,000 in 1800 and continued to grow at an increasing pace of for each decade until, by 1860, the nation's 1.65 billion pounds of cotton was being produced on the figurative backs of just under 4 million slaves.

It is safe to say that none of this would have happened had Whitney not invented the cotton gin. Arriving on the economic scene at time when the number of slaves in the United States as well as their role in the economy were steadily diminishing, the cotton gin reversed a national trend and upended a national culture. Indeed, while there is evidence that without the new demand created by the gin, slavery might well have faded away, instead, fueled by the wave of cotton growing facilitated by the invention, development, and utilization of the cotton gin, the nation's fortunes took a very different turn—one that would ultimately result in the Civil War. In a comparatively brief period, cotton became king and the kingdom came to be maintained by a slave labor force that grew in the face of the nation's promise and at the expense of national unity.

William H. Pruden III

See also *Vol. 1, Sec. 3*: Combine Harvester; Corn Sheller; Mechanical Reaper; Polished Steel Plow

Further Reading

Green, Constance McL. 1956. *Eli Whitney and the Birth of American Technology*. Boston: Little, Brown.

Woods, Robert O. 2011. “How the Cotton Gin Started the Civil War.” *American Society of Mechanical Engineers* (ASME), March. <https://www.asme.org/engineering-topics/articles/history-of-mechanical-engineering/how-the-cotton-gin-started-the-civil-war>, accessed August 23, 2018.

Cotton Sewing Thread

Almy, Brown, & Slater of Pawtucket, Rhode Island, produced the first commercial cotton sewing thread in the United States under the patent of Hannah Wilkinson Slater (1775–1812), the first woman to receive a patent in her own name in the United States.

In the 21st century, cotton sewing thread is ubiquitous in our daily lives. It stitches clothing and upholstery, binds hardcover books, hems bed sheets, and is used throughout industry, including to seal large bags of dry food products. Prior to 1790, however, cotton was a rarity in America; labor-intensive processing made it expensive, and the fiber was considered too short and delicate for thread.

In the 1700s, silk, linen, and wool were the dominant thread fibers. Silk and linen were lightweight and strong but expensive; wool was abundant but bulky. In 1783, Martha Washington spent a year looking for imported cotton to spin in her plantation weave house. By the 1790s, home-based spinners were discovering cotton. Preserved quilts and textiles verify that individual women were spinning cotton fiber to use as thread.

Slater was still a teenager when she experimented with spinning a thin strand of imported Surinam cotton. To increase its strength, she and her sister spun two cotton strands together, creating a two-ply thread. While a few women may have been spinning cotton for home use, Slater envisioned mechanized production.

Born Hannah Wilkinson, her Quaker family encouraged bold problem solving. Her father, Oziel

Wilkinson (1744–1815), and brother David Wilkinson (1771–1852) were ironworkers alongside the descendants of Joseph Jencks. The Jencks’s forge established Pawtucket as a center for technological innovation. The Wilkinsons were known for casting large ship anchors, forging steel tools, and designing iron fittings for drawbridges. Slater’s brother patented his own inventions and became renowned as a mechanical tool machinist.

In 1790, Quaker investors hired Samuel Slater (1768–1835) to set up the first American hydropowered cotton mill in Pawtucket. The young immigrant stayed with the Wilkinson family and employed the mechanical skills of father and son to recreate the Arkwright carding-and-spinning machinery he had supervised in England.

The mill opened in 1791, and Hannah and Samuel were married. The young bride realized that the technology used to spin yarn and warp for cloth could be adapted to produce cotton sewing thread. She received a patent from the U.S. Patent Office in 1793. The Slater mill produced two-ply cotton thread and sold it by the “hank”—a specified length of coiled thread or yarn.

Other companies built on Slater’s idea creating four-ply and eventually six-ply cotton thread. Slater died at age 37, soon after the birth of her ninth child.

Synchronicity between the inventions of the cotton gin, cotton sewing thread, and textile manufacturing dramatically increased the demand for cotton. The American South transformed its economy to one that produced cheap cotton. Almost overnight, cotton in America went from uncommon to factory produced, never playing a large role in homespun textiles.

Keri Dearborn

See also Cotton Gin; Greene, Catharine Littlefield; Patent and Copyright Statutes; Screw-Cutting Lathe; Slater, Samuel; Whitney, Eli; *Vol. 1, Sec. 1*: Loom; “Saugus Pot”; Spinning Wheel

Further Reading

Gies, Joseph, and Frances Gies. 1976. *The Ingenious Yankees*. New York: Thomas Y. Crowell.

Slater Trust Company. 1917. *Pawtucket Past and Present: Being a Brief Account of the Beginning and Progress of Its Industries and a Resume of Early History of the City*. Chicago: University of Chicago Press.

Dental Floss

The invention of dental floss, a cleaning aid used to remove food particles between teeth and to prevent plaque and tooth decay, is credited to Levi Spear Parmly. In 1815, New Orleans dentist Parmly, who is considered the father of oral hygiene, observed that dental caries began on the surface of the tooth's enamel. Noticing that plaque adhered to surfaces below the gumline, in the gingival area, he concluded that subsequent decay of the tooth resulted from inadequate brushing and from an incomplete removal of residual food particles. In 1819, Parmly stated that cavities could be prevented by brushing the teeth, by applying a dentifrice polisher of table salt, and by using a waxed silken thread between the teeth and around the gums to dislodge any "irritating matter" that a brush could not reach.

Techniques to remove food stuck between the teeth had been around long before Parmly, but he was the first dentist to recommend habitual brushing and flossing. In his book *A Practical Guide to the Management of the Teeth*, Parmly expressed the view that dental caries were caused by external influences related to foreign material on the teeth and that gum tissue could be improved by regular and systematic brushing and flossing. His insight predated knowledge of dental plaque and a scientific understanding of oral bacteria. Parmly described the process of how the toothbrush and floss should be used: rather delicately at first, until the gums had become accustomed to the procedure. After a few days, the gums, he stated, will respond favorably, "harden," and no longer bleed or hurt. Parmly advised his patients to use string flossing—a thin silk thread coated in wax—to clean between the teeth to prevent tooth decay.

For several reasons, however, dental floss did not achieve popularity. First, dental education was in its early stages. In the 1800s, professional dentistry was still a developing field, establishing its own identity by severing its connection with barbers and surgeons and by asserting itself as a health discipline in its own right, separate from but in concert with medicine. The first dental book published in America was Richard C. Skinner's *Treatise on the Human Teeth* (1801). The world's first dental school, the Baltimore College of

Dental Surgery, was founded in 1840 and established the doctor of dental surgery (DDS) degree. The American Dental Association was formed in 1859 when 26 dentists met in Niagara Falls, New York. Through his vision for the education of dentists, Parmly was instrumental in impacting Anglo American dental schools regarding the study, duties, practice, and qualifications of dentists.

Another reason that dental floss did not achieve immediate success involved the silk thread. Silk was expensive, and sericulture (silk culture) in America, which dates to 1603, when silkworm eggs and mulberry seeds were sent to Virginia by order of King James, was a struggling industry and never became very large or profitable. The entire silk production process was labor-intensive, requiring favorable growing conditions. Consequently, no commercial "dental floss" industries emerged.

Although historians credit Parmly with the invention of modern dental floss, he did not apply for a patent. Instead, the first patent for a dental floss device, a pocket thread carrier and cutter that is similar to contemporary dental floss packages, was granted in 1874 to Asahel M. Shurtleff. In his patent, Shurtleff mentioned silk as the best material and the least harmful agent for removing foreign matter from between the teeth. Shurtleff's company began to provide unwaxed silk floss for home use in 1882.

Shortly after World War II, Dr. Charles C. Bass, a New Orleans physician, created nylon floss as a substitute for silk floss. Through his research, he expanded upon Parmly's concepts of oral disease, demonstrating that microscopic processes cause tooth decay, and he advocated the Bass method of brushing and flossing before bedtime. Modern dental professionals routinely promote dental floss as a critical component of good dental health.

Carol E. Dietrich

See also *Vol. 1, Sec. 3*: Colgate, William

Further Reading

Chernin, D., and G. Shklar. 2003. "Levi Spear Parmly: Father of Dental Hygiene and Children's Dentistry in America." *Journal of the History of Dentistry* 51, no. 2 (March): 15–18.

Parmly, L. S. 1819. *A Practical Guide to the Management of the Teeth: Comprising a Discovery of the Origin of Caries, or Decay of the Teeth*. Philadelphia: Collins & Croft.

Sanoudos, M., and A. G. Christen. 1999. "Levi Spear Parmly: The Apostle of Dental Hygiene." *Journal of the History of Dentistry* 47, no. 1 (March): 3–6.

Diffraction Grating

In a multifaceted career that stamped him as one of the preeminent scientists of the 18th century, one of inventor and astronomer David Rittenhouse's most important accomplishments was his creation of the first man-made diffraction grating. That innovation, typical of a career marked by an exceptional number of path-breaking discoveries and inventions, opened the door to new opportunities for scientists in numerous areas.

The basic principle of diffraction grating were discovered by James Gregory approximately a year after Isaac Newton had conducted a series of experiments relating to light and glass prisms. Building on Newton's discovery that light was composed of a spectrum of seven distinct colors, Gregory developed the idea of a diffraction grating, which is "a band of equidistant, parallel lines, usually more than 5000 per inch (2000 per centimeter), ruled on a glass or polished metal surface for diffracting light to produce optical spectra." The diffraction grating essentially serves as a "super prism" and thus leads to an application for measuring atomic spectra in both laboratory instruments and telescopes. The diffraction grating itself consists of a large number of parallel, closely spaced slits. In its most effective usage, a diffraction grating is the preferred tool for separating the colors in incident light.

Seeking to achieve this effect, Gregory's initial work involved the use of bird feathers, which, while effectively able to separate light of different wavelengths with high resolution, lacked a needed consistency since each feather was different. Consequently, when Rittenhouse made his initial prototype in 1785, creating an instrument by stringing hairs between two fine-headed screws, he provided the desired consistency, as well as the ability to replicate experiments and work with light, that had previously been missing. At the same time, it must be acknowledged that his

early efforts were rough and rather imprecise, a reality that limited their initial usefulness. However, in demonstrating how scientists could themselves make the instrument, he not only made it possible for them to utilize the process when and how they wished, but he also provided the foundation from which future work could be pursued. Indeed, from that foundation, they could then investigate ways to improve the precision and expand the application of the diffraction grating.

Rittenhouse's creation has, according to some historians of science, proven to be one of the most valuable instruments ever developed. Indeed, its impact has included giving scientists the ability to study celestial bodies. It has also been a critical tool in scientists' work studying atomic and molecular structures. The ability to disperse light in the way it does is invaluable to a wide range of scientific exploration. In fact, diffraction gratings have many applications, being used in items ranging from spectrometers to lasers, and they also are a central component in many optical instruments. While the average person unversed in higher-level physics may not relate to the concepts that make the diffraction grating so important, it actually plays no small role in modern lives given that the basic CD and DVD media so central to entertainment today are examples of ways that diffraction grating can be used, while diffraction gratings are also used to distribute the light in products like the Nook GlowLight e-reader. Rittenhouse's invention resonates on a daily basis around the world.

William H. Pruden III

See also *Vol. 1, Sec. 1*: Rittenhouse, David; *Vol. 3, Sec. 2*: CD and DVD

Further Reading

"Diffraction Grating." <http://hyperphysics.phy-astr.gsu.edu/hbase/phyopt/grating.html>, accessed August 23, 2018.

Ford, J. Edward. 1946. *David Rittenhouse, Astronomer-Patriot, 1732–1796*. Philadelphia: University of Pennsylvania.

O'Connor, J. J., and E. F. Robertson. n.d. *David Rittenhouse*. St. Andrews, Scotland: School of Mathematics and Statistics, University of St. Andrews. <http://www-history.mcs.st-and.ac.uk/Biographies/Rittenhouse.html>, accessed August 23, 2018.

Erie Canal

Built to cross New York state from the Atlantic Ocean to Lake Ontario, the Erie Canal traverses 363 miles from Albany to Buffalo. Built between 1817 and 1825, the canal was an engineering marvel of its time. Part of the New York State Canal System, this long stretch of water created a link between the waters of Lake Erie and the Hudson River, the first waterway to do so. In its time, it was the second-largest canal in the world, behind the Grand Canal in China. The creation of the Erie Canal led to an enormous growth in opportunities for the East Coast. This great North American public work established New York as the pioneer of population and transportation and as an economic powerhouse.

Rivers served as perfect waterways in the East Coast, but multiple obstacles lowered their availability as transportation. The Appalachian Mountains posed a great challenge to travel and commerce, particularly in an age when roads were poorly maintained. Goods and people had to travel overland, making the trip slow and costly.

To surpass these obstacles, prominent New Yorkers proposed the canal in 1768. The first proposal focused on improving the Mohawk River so that it was more navigable. The river, north of the Appalachian Mountains appeared promising until surveyors discovered that its level above that of seawater varied greatly. Thus, the challenge of the canal increased exponentially. For the canal to work, locks were created to



The Erie Canal at Salina St. in Syracuse, New York, ca. 1900. Canals include a series of dams and locks that create reservoirs of low-speed current flow to allow ships to traverse waterways that were once thought impassable. (Library of Congress)

balance out the different levels of land, essentially allowing boats to move up a grade.

The idea seemed preposterous to many people, both because of its size and because of the building expense. President Thomas Jefferson quickly rejected the proposal. However, DeWitt Clinton, the governor of New York, became interested in the project. Clinton became the most persistent and passionate advocate for the canal. He oversaw the first ideas of a cross-state canal and led the effort. Many people sarcastically referred to his idea as “Clinton’s Big Ditch.” He worked endlessly to gather support for the canal, garnering private funding and lobbying for public funding. On July 4, 1817, construction began.

The construction of the Erie Canal proved a difficult task, particularly as it passed through limestone and mountains. Early versions of the bulldozer were used, along with animals, to move earth and rock. The bottom and sides of the canal were lined with stone set in clay. There were no civil engineers in the United States in the early 1800s, so surveyors and engineers had to invent the engineering as they worked. The lead engineer, Benjamin Wright, and James Geddes laid out the route. Canvass White, also one of the engineers, traveled to Britain to study its canal system to help contribute to and improve the Erie’s construction. Many of the workers hired to build the canal were Irish, who were mostly recent immigrants.

When finally completed on October 26, 1825, the Erie Canal had 18 aqueducts and 83 locks. The total rise in feet from the Hudson to Lake Erie was 568. The canal was 4 feet deep, 40 feet wide, and transported boats with over 30 tons of freight. The canal boats were pulled by horses and/or mules on the towpath along the water, generally toward the north. These boats moved quite slowly, but when looking at the bigger picture, this still decreased the time and distance of travel dramatically compared to other forms of transportation at the time. It easily cut travel time in half. The Erie Canal snaked through forests, fields, mountains, and swamps. New York now had an effective way of not only transporting goods but also people. Men and women boarded boats to travel westward to visit family, find goods, and sometimes just for a relaxing journey. Immigrants began to use the

freight boats to move to new areas and start new lives. This quick and easy way of transportation helped spread the population and made New York a famous stop. New York was now an epicenter of trade for goods.

The Erie Canal also went through modifications and improvements to help keep up with its popularity. The “First Enlargement” widened the canal to 70 feet and deepened it to 7 feet. The number of locks was also reduced to 72. Now, the canal is about 12 feet deep, about 150 feet wide, and has 36 locks.

Early supporters of the Erie Canal believed it would bring the Union together by strengthening connections between the East and unsettled territories to the West. The impact of this canal dropped the cost of shipping between the Midwest and the Northeast, also lowering the prices of food and goods to and from. Tolls were collected on freight as they passed through, leading to an abundance of money due to the canal’s popularity. Total tolls collected already surpassed the construction costs after only one year of operation. This engineering success also led to economic growth, such as increases in people’s desire for education, and competition between port cities to better themselves.

The canal’s importance faded due to the increase in railroads, which provided faster and more flexible transportation of goods and people. Nonetheless, the canal still was able to handle 13 times more freight capacity than all the railroads in New York. The canal competed with railroads in the 19th century and with interstate highways in the 20th century. Yet, the canal is still the most fuel-efficient way to transport goods between the East and Midwest.

The Erie Canal gave 19th-century New York a huge commercial and technological advantage. It cut transport costs by almost 95 percent, making that city one of the most important and efficient ports in the country. The Erie Canal opened up a new highway for trade and boosted its surrounding economy. In competition, other port cities like Philadelphia and Baltimore began constructing their own canals, which led to industrial and economic advancement. The creation of the Erie Canal led to a domino effect of increased and widespread technology to improve trade.

Julian Gliniecki

See also Amphibious Steam Vehicle; Canals; Charting the Gulf Stream; Steamboat; *Vol. 1, Sec. 3: Railroads*

Further Reading

Andrist, Ralph. 2016. *The Erie Canal*. Scotts Valley, CA: CreateSpace.

Bernstein, Peter. 2005. *The Wedding of the Waters: The Erie Canal and the Making of a Great Nation*. New York: W. W. Norton.

Sheriff, Carol. 1997. *The Artificial River: The Erie Canal and the Paradox of Progress, 1817–1862*. New York: Hill and Wang.

Primary Document: Letter of Robert Fulton to George Washington Urging Him to Support the Construction of Canals (1797)

Although construction on the Erie Canal began in 1817, canal proponents had begun lobbying for it and other canals decades earlier. In 1797, Robert Fulton, primarily famous as the inventor of a steamboat, wrote the following letter to George Washington to urge him to support a canal.

HIS EXCELLENCY GEORGE WASHINGTON.
LONDON, February 4th, 1797.

SIR,—Last evening Mr. King presented me with your Letter acquainting me of the Receipt of my publication on Small Canals, which I hope you will soon have time to Peruse in a tranquil retirement from the Buisy operations of a Public Life. Therefore looking forward to that period when the whole force of your Mind will Act upon the Internal improvement of our Country, by Promoting Agriculture and Manufactures: I have little doubt but easy Conveyance, the Great agent to other improvements will have its due weight And meet your patronage.

For the mode of giving easy Communication to every part of the American States, I beg leave to draw your Particular attention to the Last Chapter on Creative Canals; and the expanded mind will trace down the time when they will penetrate into every district Carrying with them the means of facilitating Manual Labour and rendering it productive. But how to Raise a Sum in the different States has been my greatest difficulty. I first Considered them as National Works. But perhaps an Incorporated Company of Subscribers, who should be bound to apply half or a part of their profits to extension would be the best mode. As it would then be their interest to Promote the work: *And guard their emoluments.*

That such a Work would answer to Subscribers appears from such Informations as I have Collected,

Reletive to the Carriage from the neighbourhood of Lancaster, to Philadelphia. To me it appears that a Canal on the Small Scale might have been made to Lancaster for 120 thousand £ and that the carriage at 20 shillings per ton would pay 14 thousand per annum of which 7000 to Subscribers and 7000 to extension. By this means in about 10 years they would touch the Susquehanna, and the trade would then so much increase as to produce 30,000 per annum, of which 15,000 to Subscribers, the Remainder to extension; Continuing this till in about 20 years the Canal would run into Lake Erie, Yielding a produce of 100,000 per annum or 50 thousand £ to Subscribers which is 40 per cent.; hence the Inducement to subscribe to such undertakings.

Proceeding in this manner I find that In about 60 or 70 years Pensilvania would have 9360 miles of Canal equal to Bringing Water Carriage within the easy Reach of every house, nor would any house be more than 10 or 14 miles from a Canal. By this time the whole Carriage of the country would Come on Water even to Passengers—and following the present Rate of Carriage on the Lancaster Road, it appears that the tolls would amount to 4,000,000 per year. Yet no one would pay more than 21 shillings and 8d per ton whatever might be the distance Conveyed; the whole would also be *Pond Canal* on which there is an equal facility of conveyance each way. Having made this Calculation to Show that the Creative System, would be productive of Great emolument, to Subscribers, it is only further to be observed that if each State was to Commence a Creative System It would fill the whole Country, and in Less than a Century bring Water Carriage within the easy Cartage of every Acre of the American States,—conveying the Surplus Labours of one hundred Millions of Men.

Hence Seeing that by System this must be the Result, I feel anxious that the Public mind may be awakened to their true Interest: And Instead of directing Turnpike Roads towards the Interior Country or expending Large Sums in River Navigations— Which must ever be precarious and lead [no where] I could wish to See the Labour, and funds applied to Such a System As would penetrate the Interior Country And bind the Whole In the bonds of Social Intercourse.

The Importance of this Subject I hope will plead my excuse for troubeling you with So long a Letter, And in expectation of being Favoured with your thoughts on the System and mode of Carrying it into effect, I remain with the utmost

Esteem and Sincere Respect,
Your most obedient Servant
ROBT. FULTON.

Source: George Washington Papers, Library of Congress.

Evans, Oliver (1755–1819)

A visionary inventor whose designs were often far ahead of the state of the technology of his day, Oliver Evans is best known for his invention of an automated flour mill and his development of the high-pressure steam engine. The automated flour mill was a first step toward the kind of assembly-line manufacturing that would characterize American industry in the late 19th and early 20th centuries. The high-pressure steam engine made possible smaller units that produced more power, and thus they were adaptable for ships and eventually railroad locomotives.

Evans was born on his family farm near Newport, Delaware, on April 15, 1755. When he was 17, his father apprenticed him to a wheelwright who also built wagons. Evans had no formal higher education, although he read widely in the fields of mathematics and manufacturing. One of his first inventions was a machine to make combs with wire teeth to be used in the carding process of textile manufacturing.

In 1782, Evans and two of his brothers bought some land from their father and built a flour mill. In 1784, at a facility on Red Clay Creek near Philadelphia, Pennsylvania, Evans built a completely automated mill that could turn wheat into flour with no human labor after being started. The mill was powered by a waterwheel, and none of the various subassemblies that made up the mill was a new invention, but putting them all together in a mechanical system was Evans's real achievement.

Evans patented the design (the third patent issued by the U.S. Patent Board), and while millers were

slow to embrace Miller's design, eventually license fees from this patent brought him a significant income. In 1795, Evans published a book on mill operations, *The Young Mill-Wright and Miller's Guide*, which was republished in 15 editions over the next 50 years. Many books in those days were sold to subscribers who committed in advance to buy them; the subscribers to Evans's book included George Washington, Thomas Jefferson, and Edmund Randolph, the first attorney general of the United States.

Since his youth, Evans had been fascinated with steam power. The earliest steam engines, such as those invented by James Watt in 1765, were low-pressure machines. Evans knew that machines operating on higher pressure could be smaller and yet more powerful. He believed that iron-making and machinery-making technology had advanced sufficiently to make a high-pressure steam engine a possibility.

In 1801, he built a high-pressure stationary engine for crushing stone, and in 1805, he built a steam-powered dredger called the *Oruktor Amphibolos*, or the "Amphibious Digger." It had wheels to run on land as well as water, making it the first mechanically powered land vehicle built in America. While Evans was developing the high-pressure steam engine in America, Richard Trevithick was working on the same concept in Great Britain and actually built such an engine before Evans. But historians of technology today generally credit both Trevithick and Evans with important advances in steam technology.

In 1806, Evans built the Mars Iron Works in Philadelphia and manufactured many different products there, including over 100 steam engines that were used

in a variety of applications. A fire in 1819 destroyed much of this plant, including many of Evans's unique molds and patterns. His sons eventually rebuilt the plant on a larger scale outside of Philadelphia. In his later years, Evans became involved in many patent disputes, instigating suits against millers whom he alleged were using some of his designs without license. He also became embittered by the American public's slowness to see the need for industrial advances and to accept new technology.

In 1783, Evans married Sarah Tomlinson, the daughter of a farmer from the Wilmington, Delaware, area. They had three sons and four daughters. Sarah Evans died in 1816, and two years later, Evans married

Hetty Ward, the daughter of a New York innkeeper. Evans lived the rest of his life in New York and died in New York City on April 15, 1819, just days after hearing of the fire that had destroyed his Mars Iron Works.

Mark S. Joy

See also High-Pressure Steam Engine

Further Reading

Ferguson, Eugene S. 1980. *Oliver Evans, Inventive Genius of the American Industrial Revolution*. Greenville, DE: Hagley Museum.

Gordon, John Steele. 2001. *The Business of America*. New York: Walker.

Primary Document: Letters from Oliver Evans to Thomas Jefferson (1804, 1808)

The following are two letters from Oliver Evans, inventor of the automated flour mill, to Thomas Jefferson regarding patent rights for his mills.

Washington Decr 24th 1804

Sir

Having heard Several members of Congress express that the President delighted much in hearing of useful Mechanical & Philosophical improvements being discovered in this country Be pleased to accept of the enclosed description which I have laid before the members of congress individually in support of my application to them for an extention of my Patent Term for my improvements on merchant Flour Mills to enable me to continue my expensive experiments in persuit of other usefull improvements which I have therin described—I am

Sir with the most profound respect your Obdt Huml Servt

Oliver Evans

Philadelphia December 9th 1808

Respected Sir

Last evening I received yours of 6th Inst enclosing 89 60/100 Dolls The sum which I suppose Captn John

Moody who is acting as my Agent in Virginia has stated to Your Excellency as due me for Licence to use my improvements in your Mills in Albemarle County For which I return you my sincere thanks Mr Moody has sent me a copy of your answer to his application Which I hope will induce others to follow your generous and Patriotic example I am sensible that the law ded not require of you or any who erected and used my improvements during the interval of my patents such payments on the grounds which I have reason to suppose has been stated by Mr Moody

I beg leave to state that I beleive Congress by the act entitled "An act for the releif of Oliver Evans" Did intend (without giving any retrospective effect) to authorise me to demand payment of all those (at least) who had my improvements in use during my patent term providing they continue to use after the Commencement of my present patent The [Provises?] Cover all from damages for what had been done purposely to remove the Idea of any retrospective effect The act securing to me the exclusive right to use, Can licence no other person

But as I have raised my price for licences from 40\$ to 100 dols under my present patent for each Mill of one water wheel and as those who erected during the term of my first patent expected licence at my old price Therefore I instruct my agents to offer to receive the Old price with interest of all such who are willing

to pay freely I Can say with truth that had all that used my improvements paid as generously as the President I might been enabled to render much greater services to my Country Boats propelled by my improved Steam Engines should have ascended the Mississippi before this day at a rate of 50 miles in 12 hours with good loads for it is a fact that they exert from five to ten times the power of the best english Engines in proportion to bulk and weight Yet I have been able in 4 years to enduce but one man to apply one to steady use. It is I beleive the best in the

world has cleared for him 20,000\$ in one year and has never went rong so as to stop the Mill one hour It is at Manehast on the Mississippi Sawing timber The working Cylinder is 9 Inches diameter 3 feet length of stroke The property of Wm donaldson of New Orleans

Sir your much Oblidged obt Huml Servt

Oliver Evans

Source: Thomas Jefferson Papers, Library of Congress.

Factory Girls' Association (Lowell, Massachusetts). See Lowell Mill System

Fire Hydrant

Frederick Graff, an engineer in Philadelphia, invented the fire hydrant in 1801. Also called fireplugs, fire hydrants provided firefighters with connections to city water sources so that trucks no longer had to carry their own water. Fire hydrants open with special wrenches and are often color coded depending upon their use.

Graff was born in Philadelphia in 1775. He started his career as a carpenter but later was employed as an assistant to B. H. Latrobe, who was in charge of developing Philadelphia's first waterworks. At that time, water pipes were made out of wood, and in the event of a fire, firefighters would dig for a pipe, make a hole in it, and use the water from the pond that formed to fill up their buckets or pumps. After the fire, the hole would be closed with a wooden cone called a "fire-plug," but the hole could be used again if there was another fire in the same area.

Graff, who was chief engineer of the Fairmount River works project, suggested the use of "ready to use" hydrants to speed water delivery and applied for a patent of his own design (1801). The hydrant was a pillar type with a wet barrel design and valve on top. The actual design, however, cannot be verified,

because Graff's patent was lost in a fire at the patent office. Graff developed an improved version of his hydrant the following year, with a valve at the bottom of the body. That same year (1802), the first order for his cast-iron fire hydrants was placed with the Foxwell & Richards Company, the large cannon maker, and Philadelphia became the first U.S. city with hydrants. Because the pipes were wooden, the hydrants had to be connected with a specially designed joint. By 1811, Philadelphia was reported to have 185 cast-iron fire hydrants and more than 200 wooden ones.

Although early fire hydrants worked well in warm months, they froze during winter. To mitigate the problem, Graff's son suggested using a wooden casting over each hydrant. Nevertheless, freezing remained a serious issue, so cities with harsh winters, like Buffalo, New York, continued to install only wooden hydrants until 1869.

The R. D. Wood Company was founded the same year that the improved F. Graff Sr. hydrant was introduced. In 1858, the company patented its own non-freezing hydrant known as the Race & Mathews hydrant, and it became the main producer of hydrants for Philadelphia after moving there in 1871.

Despite the widespread availability of fire hydrants, the ordinary pressure of the water system was ineffective in high-population-density areas with tall buildings. In 1903, Philadelphia became the first city in the world to implement a high-pressure water system capable of delivering water to the red Race & Mathews hydrants throughout the city, utilizing a system of dedicated pipes that made the hydrants operable

within two minutes of a fire signal. The total pipe length was about 56 miles and worked well until it was decommissioned in 2005.

Fire hydrants or plugs are so common in American cities today that they are nearly invisible. Though traditionally painted red, they are now color coded depending upon the class of hydrant.

Stefka Tzanova

See also *Vol. 1, Sec. 3: Fire Alarm Call Box; Vol. 2, Sec. 1: Asphalt*

Further Reading

Richardson, Edgar P. 1982. *Philadelphia: A 300 Year History*. New York: W. W. Norton.

Primary Document: Account of the Detroit Fire (1805)

Fire was one of the greatest threats to early American cities. The invention of fire hydrants and their installation in cities and towns fundamentally changed American history by making fires easier to fight and thus less destructive and deadly. The following is an article from the Baltimore Intelligencer about the 1805 Detroit Fire, often called the Great Fire, which nearly destroyed the city. The city had no professional fire brigades and no fire hydrants, and thus it fought the fire with volunteer "bucket brigades" that proved vastly inadequate to the task.

This event happened on the 11th of June last. The flames commenced about 9 o'clock in the morning and within four hours the whole town was laid in ashes. Only two or three buildings, of little value, situated in the borders, were preserved. About three hundred edifices, of all kinds, were consumed, among which were nearly an hundred dwelling houses, the church, several stores, the citadel, with officers' and soldiers' barracks, contractors' stores, United States store, etc. The new fort and barracks, called Fort Lernoult, a little back of the town, were not greatly endangered, and the old Block house, at the south end, escaped. In a word, all the space enclosed within picquets, and denominated the town, presents nothing but a heap of ruins, consisting of naked chimnies and cinders. The rapidity of the destruction was perhaps unprecedented, but will not appear surprising to anyone previously acquainted with the place. The buildings were mostly old, all of wood, and dry as tinder extremely crowded together on an area of about three acres—the streets very narrow (the widest not exceeding twenty feet), intersecting rectangularly at small distances—and

every square completely covered with combustibles. This mode of building the town originated, not merely for want of taste in the ancient settlers, but from the necessity of defense in war, ad this settlement has for a long time been a frontier particularly exposed to danger from the natives, and far removed from the means of external succor. It has been found necessary, till very lately, to keep the picquets enclosing the town in repair, besides being under the protection of the common of an adjoining fort and block house. The town was furnished with but one fire engine, which, with the prompt assistance of the troops formerly stationed here, has been sufficient to extinguish occasional fires upon their first appearance; but at present the troops at this station are few and want of aid from that source was severely felt on the late occasion. By what means the fire was kindled, whether by accident or design, is uncertain—there are various conjectures, but no decided opinion. It began in a stable near the United States store, on the southwest quarter, a light breeze blowing from the south. Its progress against and athwart the wind was astonishing, but in the direction of it the blaze darted with nearly the celerity of lightning, and reached the opposite extremity of the town in a very few moments. The fire in no part had diminished till the whole was in a blaze, and one immense mass of flame was presented to the eye, having the appearance of proceeding from one building of vast extent. The streets became impassable as the fire progressed, being filled from side to side with an impenetrable column of smoke and flame, which, wafted by the current of air through the north and south streets, streamed to a great distance beyond the limits of the houses. To the distant spectator, and to the wretched

inhabitants, who after a short lapse of time could be no more than spectators, the sense was at once sublime and painful, exceeding in awful grandeur perhaps almost any spectacle of the kind which has happened since the world began. It was fortunate that the catastrophe did not take place in the night, as there must have been a greater destruction of goods and effects and unquestionably of some lives. No lives were lost, but one person (a poor woman) was badly injured. Means have been taken to ascertain correctly the amount of losses in property, and progress has been made so far as to place it beyond a doubt that they exceed one hundred and thirty thousand dollars, probably reaching near one hundred and fifty thousand dollars. The conflagration took place at a time of day that the inhabitants were generally near their homes, and were enabled to save more of their moveable effects than could have been expected in so short a time as was allowed them; great quantities, however, fell a sacrifice, and individuals whose estates consisted in buildings, were in one day reduced from eligible circumstances to poverty. There is no citizen but who has suffered more or less. At present the people are scattered up and down the settlement, crowding the houses even to overflowing, occupying hovels and everything having the shape of an edifice, and several families are encamped in booths upon the public common and the highways. The sufferings of the people in the

ensuing winter must inevitably be great. We tremble to anticipate them. Hemmed in on every side by the wilderness, in some directions interminable, and in others extending too great a distance to admit of being passed by an impoverished people, they are restricted to the settlement, narrow in its extent, with indifferent cultivations, and the houses in bad repair. Not a farm is cultivated one mile from the river bank, nor a building erected. There the wilderness commences and extends to the western ocean. The settlement up and down the back of the river is but a few miles in extent, and taken up by farmers, who have no room to spare in their dwellings and raise barely a sufficiency for the supply of their own wants. The houseless sufferers have little time, and still less means, to provide new accommodations for themselves before the approach of the cold season. Provisions of every kind are at an excessively high price. Thus circumstanced, what can be before these miserable people but a winter of rigorous suffering! If credit and charity should furnish them with food, yet there cannot be shelter and covering sufficient for their comfort. Applications for relief are sent and are sending to various parts of the United States and Canada, which it is hoped and believed with not be sent in vain.

Source: "The Conflagration of Detroit." *Baltimore Intelligencer*, September 6, 1805.

Fitch, John (1743–1798)

John Fitch was an inventor and the man generally credited with inventing the steamboat. However, numerous factors have prevented him from earning the recognition that successors who built upon the basic invention have earned.

John Fitch was born on January 21, 1743, in Windsor, Connecticut, to Joseph and Sarah Shaler Fitch. Fitch received little formal education but from an early age showed an impressive mechanical aptitude. Utilizing those mechanical skills, he engaged in a wide range of endeavors, including clock making and map-making. On December 29, 1767, he married Lucy Roberts, with whom he would have a son, and soon

afterward opened a foundry in West Windsor. That venture proved unsuccessful, but a subsequent brass- and silversmithing operation flourished until destroyed by British forces during the American Revolution. Fitch served as a soldier in the Continental Army, helping secure supplies for it, including the forces at Valley Forge. Following the war, Fitch explored the West, venturing into the Ohio River Valley and recording an extensive land claim in Kentucky. Working as a surveyor in the Northwest Territory, he was held captive for brief period by some Native Americans before being released to the British forces still in the area.

Returning to Philadelphia, Fitch began to work on his idea for a boat powered by steam. His request for funding from the Continental Congress was rejected,

but a couple of state legislatures awarded him a steamboat traffic monopoly on their waters. With those grants, he constructed a new steam-powered vessel aptly named the *Perseverance*. The inaugural journey, the first successful trial of a steamboat, took place on the Delaware River on August 22, 1787, with a number of delegates to the Constitutional Convention in attendance. Although impressed, the delegates offered Fitch no financial support, although there are those who believe that the demonstration contributed to the Convention's decision to give Congress the power to "promote the Progress of Science and useful Arts, by securing for limited times to Authors and Inventors the exclusive Right to their respective Writings and Discoveries."

Fitch and Henry Voigt continued developing their vessel, and in the summer of 1790, they began offering round-trip cruises from Philadelphia to Burlington, New Jersey. On August 26, 1791, Fitch received a patent for his steamboat from the U.S. government's new Patent Commission, but the patent did not cover the full invention, and without the monopoly necessary for guaranteed financial success, many investors abandoned the project—leaving Fitch unable to continue operation even though the boat itself was a sounder vessel than previously.

Frustrated, Fitch went to France, where he had a promise of support to build a boat there. However, his arrival coincided with the French Revolution, and although he was able to escape to London, he had no business prospects there. He returned to the United States in 1794 but could find no investors. Desperate to raise funds, he went to Kentucky in 1797 to sell some land, only to discover that his claims were in doubt due to the squatters occupying it.

With his accomplishments unrewarded and unrecognized, unsuccessful in securing needed financial support, and battling depression, John Fitch took his own life on July 2, 1798.

William H. Pruden III

See also Steam Engine; Steamboat

Further Reading

"John Fitch." *PBS: Who Made America?* https://www.pbs.org/wgbh/theymadeamerica/whomade/fitch_hi.html, accessed August 23, 2018.

"John Fitch's Steamboat Historical Marker." *ExplorePA History.com*. <http://explorepahistory.com/hmarker.php?markerId=1-A-394>, accessed August 23, 2018.

Lienhard, John H. "John Fitch." *Engines of Our Ingenuity*. <http://www.uh.edu/engines/epi14.htm>, accessed August 23, 2018.

Flatboat

A flatboat was a square-ended boat with a flat bottom commonly used for the transportation of goods and people in the 1800s. It was primarily used on inland waterways, specifically the Mississippi River and the Ohio River. The flatboat was similar in appearance to a raft, but different in that it floated *in* the water rather than *on* it. It was typically broken down for usable lumber at the end of its journey downstream. Prior to 1812, flatboats were constructed and manned by farmers who wanted to transport their crops. They were no more than 20 feet wide, to remain smaller than the river at its narrowest point. The flatboats varied in length, however, with the smallest being 20 feet long and the largest 100 feet long. The boats were no longer than this so that the farmers could still navigate properly. The largest of all the flatboats were called things like "Mississippi broadhorn," "New Orleans boat," "barge," and "ark," for a few of the more common nicknames. In the early days of flatboats, these larger boats were susceptible to attack by Native Americans. They were therefore built like fortresses, with only one door and very small windows; they were covered along their entire length to keep their cargo safer.

Flatboats could carry variety of goods. Most commonly, agricultural goods like corn, potatoes, wheat, and whiskey were carried downstream from agricultural areas to urban areas. The boats could also accommodate livestock such as chickens, cows, and pigs. Shopkeepers used them as additional storage areas, ministers used them as chapels, and financially disadvantaged families used them as housing. They were even used as floating brothels, slyly called "gunboats." Although the type of goods transported varied, flatboats were a necessity in 19th-century America.

Jacob Yoder, a farmer, built the first flatboat to ship flour from Brownsville to New Orleans via the



A flatboat loaded with men and a cargo of animals floats down the Ohio River. Pennsylvania farmer Jacob Yoder invented the flatboat in 1781 to ship flour down the Mississippi River to the port of New Orleans. (Library of Congress)

Mississippi River. Before the War of 1812, flatboats were the preferred method of transporting goods downstream. Building and using a flatboat in the late 1700s and early 1800s took serious consideration by the farmer. Materials to build one cost about \$75 in 1800 (equivalent to over \$1,000 in 2015), but it required minimal tools and training to manufacture. The boats were especially appealing to farmers in the northern regions of the United States, who would have had no other way to export their goods to market if not for the accessible transportation that the flatboat offered.

Depending on size, some flatboats required as many as four crewmembers and a pilot. It took anywhere from a month to a month and a half to complete a journey downriver. Although the journey downstream was relatively easy, the return home was generally considerably more difficult. Because the flatboats were disassembled upon arrival at their final destination,

farmers and merchants had no easy passage back to their home bases. Passage via keelboat or hired coach was expensive. Railroads offered an affordable return passage, but rail lines didn't always go where people needed to go. People who preferred to walk spent up to three months in their travel home.

Although flatboats had their disadvantages, the benefits outweighed the cost for many Americans. For the money the farmers spent on building and the inconvenience of return travel, they could make about \$3,000 selling their crops downriver and about \$16 back on the lumber from the disassembled boat.

Flatboats also increased the amount of "exotic" trade between the northern and southern United States. Parrots and bananas returned to the North with the farmers along with tales of far-off lands in the South. Even Abraham Lincoln, the 16th president of the United States, piloted a flatboat in 1828 and again in 1831. It was during Lincoln's travels that he saw

slavery in the South firsthand, including a slave auction in New Orleans.

Since the biggest disadvantage to flatboat travel was the tedious return journey, the process to find a more convenient possibility was expedited. Many people viewed the introduction of the steamboat as the option for which people had been waiting. The popularity of the steamboat began rising in the early 1810s because of its benefits to farmers trying to return home after boating downstream. This changed the return time from months to just days. The ease of travel also cut flatboat labor costs by a large margin while maximizing profit on goods. Steamboats often also towed flatboats filled with goods upriver, which further increased farmers' incomes.

The popularity of steamboats caused over a six-fold increase in the amount of flatboat journeys and truly made the industry boom. The onset of the steamboat also changed the flatboat crews—what once was a side job for farmers had now become a skilled profession. People could make a career out of piloting a flatboat since the return journey time had so drastically decreased. This switch from “dealer boatman” to “agent boatman” greatly reduced the amount of lost cargo as well as the number of boat crashes. Poor construction and rotted wood led to many wrecks during the early flatboat era. There were no dams in place to deepen the river, so the water was meandering and shallow. The boats themselves were difficult to steer, and the “dealer boatman” (mostly farmers) often had no previous experience navigating watercraft of that size downriver. Eventually, railroads were used to take farmers back upriver after their journeys downstream. Although this expedited the process even further, the increased popularity of railroads and steamboats eventually overtook flatboats as a predominant form of transportation.

Brenna Biggs

See also Canals; Steamboat; *Vol. 1, Sec. 3: Railroads*

Further Reading

Schneider, Paul. 2013. *Old Man River: The Mississippi River in North American History*. New York: Henry Holt.

Fulton, Robert (1765–1815)

Robert Fulton was a late 18th- and early 19th-century artist-turned-inventor and businessman. While he is best known in conjunction with his development of the first commercially viable steamboat in the early 19th century, a development that changed the face of American travel and commerce, he was also a central figure in the invention of a number of other important devices in the early 1800s.

Robert Fulton was born in Little Britain in Lancaster County, Pennsylvania, on November 14, 1765, one of five children born to Robert and Mary Fulton. His father was a farmer, but he lost the family farm in 1771, which forced the family to relocate. They were living in Lancaster, Pennsylvania, when Robert Fulton Sr. died in 1774.

Robert was given his early education at home before attending a Quaker school. He initially worked at a jewelry shop in Philadelphia, where he became skilled at doing miniature portraits on ivory for lockets and rings. Seeking to further his artistic efforts while demonstrating a lifelong talent for making acquaintances of those who could further his career, Fulton met and painted a portrait of Benjamin Franklin, who provided introductions to other local luminaries who sat for the young artist.

In 1787, Fulton traveled to London, where, with the help of the painter Benjamin West, he was able to secure a number of commissions for both portraits and landscapes. While he achieved modest success, with a sampling of his work being exhibited in London's Royal Gallery, Fulton realized that his future was not in painting. Instead, he turned his focus to canal engineering, a subject in which he had become interested during his European travels. He furthered his interest and established his expertise with the publication in 1796 of *Treatise on the Improvement of Canal Navigation*, a work dealing with a comprehensive system of inland waterways.

In addition, based on his fascination with canals and steam-powered boats, the one-time artist started to design his own ships, with the dream initially of selling his creations to the British Navy. His early efforts were wide-ranging and included the development of a

torpedo as well as various aquatic vessels. Indeed, in 1797, Fulton, having developed a plan for a submarine, went to Paris and proposed to the French government that his creation be used against the British in their ongoing war. The French rejected his proposal, but in 1801, after building the *Nautilus* at his own expense, it was used against the British in an effort to sink their blockade. It proved unsuccessful. In 1804, he went to Britain, where he helped develop the first advanced-design torpedoes for the Royal Navy's forces.

Fulton returned to the United States in 1806 and, partnering with influential New York politician and one-time ambassador to France Robert Livingston, he began work on what would become the *Clermont*. Indeed, Fulton's genius came not, as is often reported, in the invention of the steamboat but rather in the development of the first commercially feasible one.

Indeed, John Fitch had developed the first successful steam powered boat in 1787. After a patent battle, Fitch shared the patent with James Rumsey and John Stevens. Failing to attain a monopoly, he lost investors and never capitalized on his invention. This created an opportunity for Robert Fulton to design and manufacture a sturdy, affordable steam-powered boat.

Fulton's steamboat, the *North River Steamboat*, later renamed the *Clermont*, had sleeping accommodation for lengthy trips and a separate lounge for women. The boat made its first trip up the Hudson River from New York City to Albany in August 1807. The ship was 142 feet long and 18 feet wide and had an average speed of 4.7 miles per hour. The ship was rebuilt during the winter of 1807 to 1808 to make her six feet wider, an improvement that stabilized the ship. The rebuilt ship also featured improved steering and rudder systems. Most important, unlike previous steamboats, the *Clermont* proved profitable.

In September 1807, Fulton and Livingston had established the North River Steamboat Company. Operating on the Hudson River between New York City and Albany, the company offered a 32-hour round-trip travel option. Before his death in 1815, Fulton had directed the construction of 17 steamboats, with another 6 of his design being constructed by other companies. By 1840, there were over a hundred steamboats on the Hudson River alone. More traveled the

Ohio River, Mississippi River, the Atlantic Ocean, and other major waterways. The 19th century was, among other things, the era of the steamboat.

With his business prospering and boats operating on rivers beyond the Hudson, Fulton pursued other interests. Befitting his longtime interest in canals, in 1811, Fulton became a member of the Erie Canal Commission. Fulton married Robert Livingston's niece, Harriet Livingston, in 1806. The couple had four children. On February 24, 1815, Robert Fulton died from pneumonia that he had developed after venturing into icy water, trying to rescue a friend from the frozen Hudson River.

Fulton remains among the most famous of American inventors. Numerous towns and counties are named after him, and there is a statue of him in the U.S. Capitol's Hall of Statues. Five U.S. Navy ships have been named USS *Fulton*, and in 2006, he was inducted into the National Inventors Hall of Fame.

William H. Pruden III

See also Erie Canal; Steam Engine; Steam Tractor; Steamboat; Submarine; *Vol. 1, Sec. 1: Turtle Submarine*

Further Reading

- Kotar, S. L., and J. E. Gessler. 2009. *The Steamboat Era: A History of Fulton's Folly on American Rivers, 1807–1860*. Jefferson, NC: McFarland.
- Sale, Kirkpatrick. 2001. *The Fire of His Genius: Robert Fulton and the American Dream*. New York: Free Press.

Gas Tungsten Arc Welding

Gas tungsten arc welding (GTAW) is a process in which an arc of electricity is created between a tungsten electrode and a piece of metal that needs to be welded. It is used on almost every metal with or without filler metal. Welded joints obtained by GTAW are very high quality and are commonly used in critical environments like nuclear and aeronautic ones. Alternative current is also used in welding for alloys that have oxide surface layers like aluminum, copper, and magnesium.

The discovery of gas tungsten welding started with short electric arc in 1800 by Humphry Davy and then in 1802 with continuous electric arc by Vasily Petrov. GTW was slowly developed because it wasn't until 1890 that C. L. Coffin had the idea of welding in an inert gas atmosphere. From the beginning, welding materials like magnesium and aluminum was difficult because of the way the metals responded to the air and resulted in porous, dross-filled welds. A solution used in the 1930s was to employ bottled inert gases; a couple of years later, the aircraft industry started to use a direct current and gas-shielded welding to weld magnesium. It wasn't until 1941 that the process was perfected thanks to Russell Meredith of Northrop Aircraft, who named the process "Heliarc." But the official term used by the American Welding Society is "gas tungsten arc welding." A chemical company helped improve the process by using a wide range of air-cooled and water-cooled torches and gas lenses, but it still had a problem because of the overheating electrode. They tried to fix this by changing the electrode from positive to negative, but that made it incompatible for welding many nonferrous materials.

Through research, it was found that alternating currents helped create high-quality magnesium and aluminum welds. Once the process became popular in the 1950s, the quality of aluminum and magnesium welding was lowered, so nowadays, it is rarely used with GTAW. The tungsten inert gas (TIG) process was fouled with the use of shielding gas that had an oxygen compound; like carbon dioxide, it ends up contaminating the tungsten electrode. In 1953, a new process called plasma arc welding was based on the development of GTAW, leading to greater control and improved weld quality by using a nozzle to focus the electric arc. However, plasma arc welding is limited to automated systems, and GTAW is a manual, handheld method.

Development within the GTAW process has continued, and today, many variations exist. Among the most popular are the pulsed-current, manual-programmed, and increased-penetration GTAW methods.

Eileen Diaz

See also Vol. 3, Sec. 1: Particle Accelerator; Plasma Arc Welding

Further Reading

- Jeffus, Larry. 1999. *The Essential Welder: Gas Tungsten Metal Arc Welding*. Detroit: Cengage Learning.
- Miller Electric. 2016. *Gas Tungsten Arc Welding: Welding Process Training Series*. Appleton, WI: Miller Electric Manufacturing.

Greene, Catharine Littlefield (1755–1814)

The widow of Revolutionary War hero Nathanael Greene, Catharine Littlefield Greene, was also probably a coinventor of the cotton gin. Catharine Littlefield Greene, known as "Caty" to her friends, demonstrated strength as a military wife, acumen as a businesswoman, and creativity as a contributor to the invention of the cotton gin. She is notable as an early American woman active in science and innovation.

Born in Block Island, Rhode Island, on February 17, 1755, Greene was daughter to Phebe Ray, a descendant of the island's founders, and John Littlefield, a Rhode Island legislator. When she was 10, her mother died and she entered the care of relatives in East Greenwich, Rhode Island. The aunt and uncle charged with Greene's care were socially and politically prominent. Her uncle, William Greene, later assumed the governorship of Rhode Island.

In 1772, Catharine Littlefield Greene met Nathanael Greene, a merchant and distant relation of her uncle. The two married in Greenwich, Rhode Island, on July 20, 1774. They made their first home in Coventry, Rhode Island. Together, they raised five children: George (b. 1776), Martha (b. 1777), Cornelia Lott (b. 1779), Nathanael Ray (b. 1780), Louisa (b. 1783). A sixth child, Catherine (b. 1785), died as an infant.

When the American Revolution began, Nathanael Greene became Rhode Island's brigadier general. Despite others' objections, Catharine Greene visited her husband in battle. When possible, she was accompanied in these travels by the couple's young children. The soldiers respected her fortitude in spending time at war-time encampments. Nathanael Greene went on to serve with the Continental Army and to command Washington's southern forces, attaining the rank of general.

After the war, Catharine and Nathanael Greene relocated to Georgia to develop land he had received in recognition of his military leadership. The property, located in the vicinity of Savannah and known as Mulberry Grove, became the family's new home. Following Nathanael Greene's death in 1786, a tutor charged with educating the Greene children stepped forward to assume additional duties, assisting Greene in managing the plantation.

At Mulberry Grove, Catharine Greene received notable visitors, including George Washington in 1791. Greene had sought for years to free her husband's estate from debts incurred during the Revolutionary War: out of urgency, Nathanael Greene had personally guaranteed the costs of acquiring sufficient clothing for his troops during a South Carolina campaign. By 1792, Washington forgave the sizable debt that had plagued the family's postwar finances.

Later that year, when Eli Whitney arrived to tutor her neighbor's children, Greene persuaded him to modify his plans. She invited the recent Yale graduate to live at Mulberry Grove and to serve as a handyman and mechanic. She also gave Whitney space for a makeshift laboratory for his scientific and mechanical experiments. During his stay at Mulberry Grove, Whitney learned from Greene about the challenges of deseeding the cotton crop. In a year's time, the two shared conversations that resulted in the design and redesign of the cotton gin.

Questions surround the origin of this invention. While accounts vary, some historians contend that it was Greene who devised the cotton gin. Others suggest that the innovation was the result of collaboration in which Greene suggested the concept and revised the original design. Other people believe that Greene underwrote the costs of the prototype and its patent. In this era, women were not permitted to hold patents, so Whitney could not have put her name on the patent even if he had wanted to.

Catharine Greene's eldest son, George, died of accidental drowning in 1793. Initially, the 18-year-old was buried on the premises at Dungeness. In 1901, George Washington Greene's remains were relocated and interred with his father's at a Savannah monument to the Revolutionary War hero.

In 1796, Catharine Littlefield Greene married Phineas Miller, the tutor who had assumed management

of Mulberry Grove. Martha and George Washington served as witnesses to the marriage. When the family sold the property two years later, they relocated to Cumberland Island, Georgia, where they presided over another plantation, Dungeness. Greene remained there following Miller's death in 1803. She died in 1814 and was buried at Dungeness.

Linda S. Watts

See also Cotton Gin; Whitney, Eli

Further Reading

Ogilvie, Marilyn Bailey. 1986. *Women in Science: Antiquity Through the Nineteenth Century*. Boston: MIT Press.

Stegeman, John F., and Janet A. Stegeman. 1977. "President Washington at Mulberry Grove." *Georgia Historical Quarterly* 61, no. 4 (Winter): 342–46.

Stegeman, John F., and Janet A. Stegeman. 1985. *Caty: A Biography of Catharine Littlefield Greene*. Athens: Brown Thrasher Books.

High-Pressure Steam Engine

The development of the high-pressure steam engine in the years between 1801 and 1806 established Oliver Evans as one of the most influential and prolific inventors in the early United States. Although credited with approximately 80 inventions, the high-pressure steam engine was Evans's most important. The engine was also the source of his deepest disappointment, as he was unable to develop and utilize the engine to the degree he believed possible.

With numerous other inventions already to his credit, including an automatic flour mill, Evans moved to Philadelphia around 1790 and turned his attention to investigating the idea of high-pressure steam power. He believed that the application of high-pressure steam to a piston would increase its effectiveness and utility, allowing for a smaller engine to do a job previously done only by a large one. In his view, the reduction in size would allow the engine to be used more broadly, even perhaps as a power source for wagons. With his dream, he foretold the "horseless carriage," or automobile.

In 1786, Evans asked the Pennsylvania legislature for an exclusive grant to build steam engines for use over the public roads. Unconvinced of the value of his idea, the legislature denied his initial request. However, in a subsequent session, it granted him the right to design a steam-propelled carriage. An inability to secure the necessary funding brought the project to a halt.

Reflective of his belief that the engine could be broadly adapted, in 1803, Evans shifted gears, unveiling a steam-powered engine that was capable of driving 12 saws through a hundred feet of marble in 12 hours. In addition, adding to its utility, the machine was portable. In 1805, under a patent originally granted in 1789, Evans created an amphibious steam-powered wagon. It was built on a commission he had gotten from the Philadelphia Board of Health. The machine, named the *Oruktor Amphibolos*, translating to “Amphibious Digger,” was a 17-ton high-pressure steam-powered dredge, whose purpose was both to deepen the Delaware River dock area as well as to clear out the muck that collected around the city’s dockyards. It was this work that finally proved the machine’s usefulness and hinted at the true potential of high-pressure steam engines. Further evidence came when a similar engine was able to power a wagon so as to transport 100 barrels of flour from Lancaster to Philadelphia in two days, a marked improvement over the three-day journey required of a normal horse-drawn transport.

In 1807, Evans founded the Mars Iron Works in Philadelphia as well as an additional factory in Pittsburgh in 1811. Both facilities were designed to build customized steam engines as well as boilers for steamboats, factories, and mills. Believing deeply in the potential of steam-powered engines and buoyed by his initial successes, Evans continued to refine the steam engine, ignoring critics who charged that it was dangerous and impractical. Indeed, as he had done to get attention for an earlier invention, the grist mill, he wrote a book, *The Young Steam Engineer’s Guide*, to help educate people. He also lobbied Congress for recognition and support.

A true visionary, Evans would not live to see his engine become a central factor in American life. Yet he anticipated what was to come. In 1812, he predicted

people driving down roads much faster than horses could take them and flying through the air with the birds: “The passengers will breakfast in Baltimore, dine in Philadelphia, and sup at New York the same day.”

Evans’s first wife, Sarah, died in 1816. He remarried to Hetty Ward in 1818. In April 1819, he learned that his Mars Iron Works had burned down. He died in New York City four days later and was buried in New York City.

William H. Pruden III

See also Fulton, Robert; Steam Engine; Steam Tractor; Steamboat

Further Reading

Hills, Richard L. 1993. *Power from Steam: A History of the Stationary Steam Engine*. Cambridge: Cambridge University Press.

Malm, Andreas. 2016. *Fossil Capital: The Rise of Steam Power and the Roots of Global Warming*. London: Verso.

Interchangeable Parts

Interchangeable parts are parts that are manufactured to be identical and thus interchangeable with others of their type. The introduction of identical parts revolutionized goods assembly, making it easier to produce large numbers of one type of product on an assembly line using unskilled laborers.

Cotton gin inventor Eli Whitney played an instrumental role in the development and implementation of the concepts of interchangeable and sequential parts, a concept that was critical to the development of mass production as well as serving as the forerunner of the assembly line that would ultimately play such an important role in revolutionizing American industry. Modern historians now view the development of the concept as a product of a number of inventors and creative individuals, including Whitney, all working around the same time with the sometimes disparate areas of their work all ultimately coming together in the development of this all-important process.

Ironically, Whitney's involvement with sequential and interchangeable parts resulted, at least in part, from frustration with his efforts to make his invention of the cotton gin profitable. With almost no profit yet realized, litigation continuing, and bankruptcy looming, in 1798, Whitney secured a contract from the U.S. government to produce 10,000 guns in anticipation of a war with France. The contract, calling for the guns to be delivered in 1800, was negotiated through fellow Connecticut native and treasury secretary Oliver Wolcott Jr., and was more a testament to his skills as a businessman and a salesman than as a gun manufacturer. Indeed, while the cotton gin had cemented his reputation as an inventor and the contract was the beginning of a robust arms business, at that point in time, Eli Whitney had no experience making guns and no real sense of how a musket was made.

But, as he had in developing the cotton gin, Whitney quickly assessed the challenge and developed a solution. Working in the New Haven, Connecticut, factory originally built to manufacture cotton gins, Whitney realized that the musket "was a complicated engine and difficult to make." Believing that the difficulty stemmed, at least in part, from the lack of consistency in its individual parts, Whitney set out to address that central concern. In typical fashion, he tinkered until, in 1798, he determined the best way to build a rifle. With that concept in hand, he designed a template for each individual piece. This allowed him to make multiple numbers of each piece, which in theory could then be assembled at will since each barrel, each stock, etc. was the same. The idea represented a major breakthrough and held great promise for future manufacturing, but it was not original to Whitney. Rather, while its origins are unclear, there is ample evidence that it was being pursued by other Americans as well as in Europe.

For all of Whitney's advances, he was unable to deliver the contracted number of rifles on time, and with Congress questioning his efforts, the creative Whitney staged a demonstration aimed at keeping his congressional benefactors at bay. While the demonstration's validity was later discredited, Whitney was reported to have assembled a number of guns from unorganized piles of unmarked parts, all lying out in

front of the congressional observers. Impressed with the demonstration, however staged it may have been, Congress subsequently issued a set of standards for U.S. equipment while also giving Whitney more time to fulfill his contract. It would ultimately take eight years for him to do so, and he would again have to respond to congressional doubters, who this time also questioned his costs. However, in another innovation, Whitney defended himself by essentially introducing the concept of cost accounting, adding another credit to his list of contributions to the developing industrial process. That, plus the quality of his guns, not only allayed the government's fears but earned him a contract for an additional 15,000, an order that was filled within four years.

In the end, the development of interchangeable parts represented a major step in the nation's industrial growth, with more products able to be produced faster, a development that allowed for greater production speed and lower costs. It also served as the foundation for the subsequent development of the assembly line. In the end, while Whitney likely did not wholly deserve all the accolades that came his way, his work was central to ushering in the American machine age.

William H. Pruden III

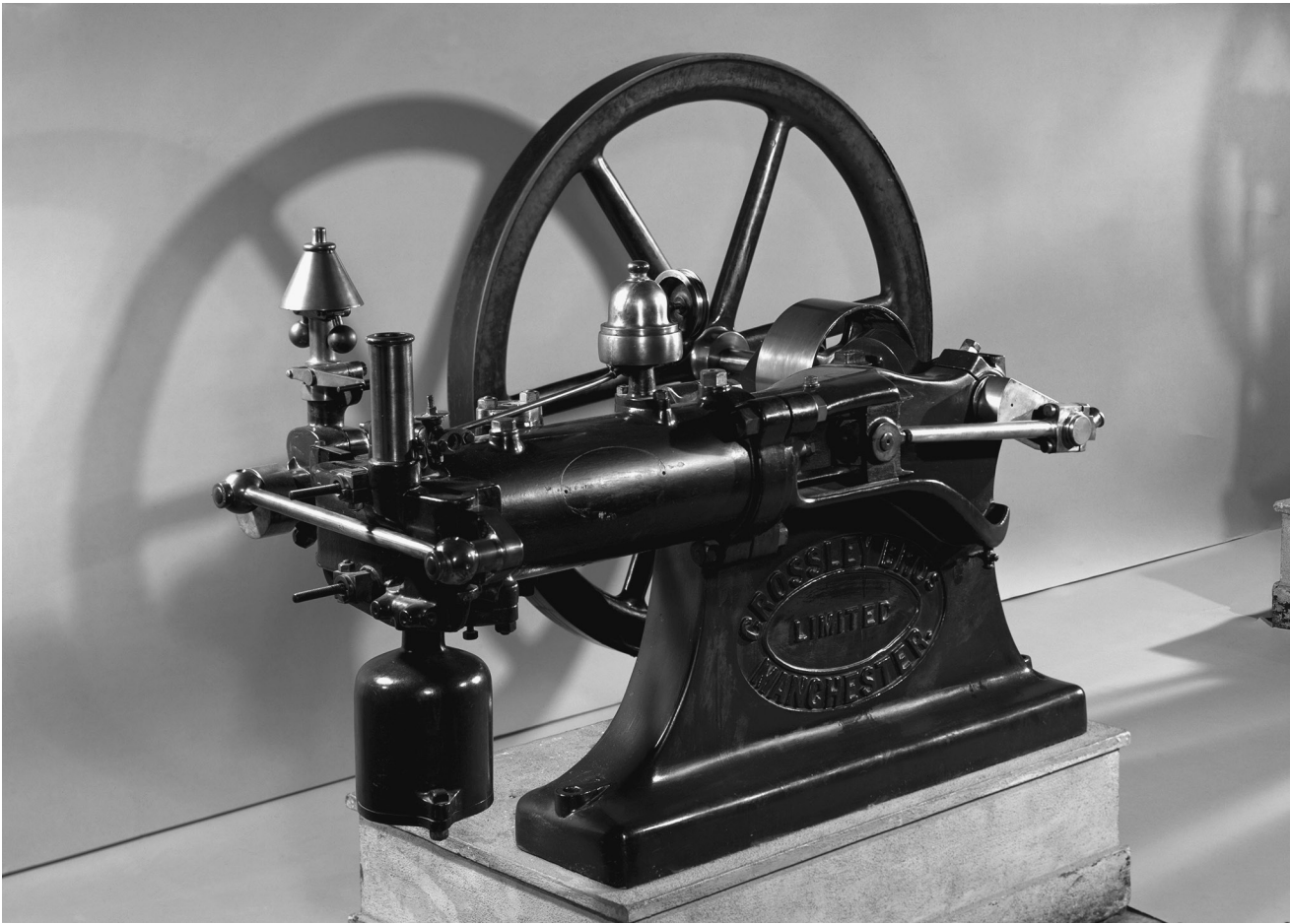
See also Cotton Gin; Whitney, Eli

Further Reading

Green, Constance McL. 1956. *Eli Whitney and the Birth of American Technology*. Boston: Little, Brown.

Internal Combustion Engine

The internal combustion engine (ICE) is a type of heat engine that generates power by burning fuel (such as petroleum or natural gas) with an oxidizer (such as air) inside a combustion chamber. The high-pressure gases produced by this process are typically applied to pistons, turbine blades, nozzles, or other mechanical parts to create desirable motion. In this process, chemical energy is transformed to mechanical energy. There are many variant of ICEs, such as two-stroke, four-stroke, or six-stroke piston engines, Wankel rotary



The four-stroke engine cycle begins when an explodable mixture of gas and air is drawn into the cylinder by the piston (induction stroke), compressed (compression stroke), and ignited (combustion stroke). (Science & Society Picture Library/Getty Images)

engines, gas turbines, jet engines, rocket engines, etc. Different type of ICEs are used in automobiles, motorcycles, ships, airplanes, rockets, and other machinery.

The first commercially successful ICE was built in 1859 by Jean J. Lenoir, a Belgian engineer; he used it in his automobile as well as in his boat. The modern ICE was first developed in 1876 by a German engineer, Nikolaus A. Otto. Many modern automobiles use four-stroke Otto cycle engines that originated from his design. In this type of engine, the piston completes four separate strokes or cycles while turning a crankshaft. These are as follows:

- 1) *Intake stroke*: In this downward stroke, the intake valve opens up, and the piston pulls an air-fuel mixture into the cylinder.
- 2) *Compression stroke*: In this upward stroke, the air-fuel mixture is compressed in preparation for ignition. Both intake and exhaust valves are closed at this point.
- 3) *Combustion or power stroke*: The highly pressurized air-fuel mixture is ignited by the spark plug (in a gasoline engine) and creates a small-scale explosion. The explosion forces the piston to move downward, which in turn rotates the crankshaft and ultimately the tires. Thus, chemical energy transforms to mechanical energy in this phase.
- 4) *Exhaust stroke*: In this upward stroke, the exhaust valve opens to release the burnt gases.

These four cycles repeat continuously to facilitate the movement of the vehicle.

Early ICEs were started by hand-cranking. However, all modern small- and medium-size ICEs use electric starters, while pneumatic starters are used for large engines.

The first commercially successful two-stroke, or two-cycle, engine was patented by Dugald Clerk in England in 1881. As the name indicates, this type of engine completes the power cycle in two strokes—*upward* and *downward*. The end of the combustion stroke and the beginning of the compression stroke take place simultaneously, while the intake and exhaust function occur at the same time. Two-stroke engines are much lighter, since they have fewer moving parts compared to four-stroke engines. The gasoline-fueled two-stroke engines have been popular for motorcycles and small engine devices such as chain saws. However, the diesel version of the two-stroke engine is also used in large operations such as marine propulsion, railway locomotives, and electricity generation. A two-stroke engine can be more efficient than a four-stroke engine, since heat transfer from the engine to the cooling system is less for the former type.

The emissions from burning gasoline contain carbon dioxide (CO₂), a greenhouse gas (GHG) that causes global warming. Many approaches are being pursued to reduce engine emissions. For example, the Environmental Protection Agency (EPA) in the United States outlined the fuel economy standard for new cars and trucks for the model years 2012 to 2025: a gradual increase to 45 miles per gallon (mpg) for average cars and 32 mpg for average trucks by 2025. This restriction will motivate companies to improve the efficiency of ICEs.

Research continues on how to improve the efficiency of both gasoline- and diesel-powered vehicles. Other renewable fuel sources, such as bioethanol, methanol, and biodiesel are also being considered to make ICEs more sustainable. Auto companies can achieve higher fuel economy and lower GHG emission, along with a reasonable price tag, in hybrid vehicles that are equipped with ICE and electric motors (e.g., the Toyota Prius). New technologies such as smaller engines with turbochargers, direct fuel injection, variable valve timing, and others are being investigated to produce more power, substantial fuel

economy, and lower GHG emissions. For example, Ford's Eco-Boost uses a combination of turbocharging and direct fuel injection to improve fuel economy without sacrificing the engine's power. Other companies such as BMW, Mercedes, Toyota, and Volkswagen are also using similar strategies in their newer models.

Mousumi Roy

See also Morey, Samuel; *Steam Engine*; *Vol. 2, Sec. 2: Automobile Technologies (Pre–World War II)*; *Motorcycle (Pre–World War II)*; *Vol. 3, Sec. 1: Automotive Technologies (Post–World War II)*; *Electric Car*

Further Reading

- Ganesan, V. 2012. *Internal Combustion Engines*. Mumbai: McGraw Hill Education (India) Pvt.
- Reitz, R. D. 2013. "Directions in Internal Combustion Engine Research." *Combustion and Flame* 1 (160): 1–8.

Jefferson, Thomas (1743–1826)

Although he is primarily known for having served as the third president of the United States of America and as the author of the American Declaration of Independence, Thomas Jefferson (1743–1826) was also a prolific inventor, with a number of original inventions and improved versions of already-existing objects to his credit including the pantograph, a revolving chair, a wheel cipher, a sundial, a pasta machine, a mold-board plow, a sundial, the Great Clock at Monticello, a revolving book stand, automatic double doors, a lap desk, the pedometer, and more. However, he never applied for a patent in his own name. This was grounded in his belief that inventions should be as widely available as possible so as to benefit all of society instead of solely making money for their creators.

Given that Jefferson was a prolific writer of letters (it is estimated that he wrote over 25,000 of them), it comes as no surprise that many of his inventions dealt with this matter. For instance, afraid of the possibility that his letters might fall into hands other than those of their intended recipients, while he was secretary of state, Jefferson designed in 1792 to 1793 a wheel cipher to encode his writings and thus keep his

correspondence secret. An improved version of Jefferson's wheel, known as M-94, was used by the U.S. Army from 1922 to World War II. Jefferson invented a lap desk holding all that he needed, including a portable printing press, while his pantograph's three arms held three pens while he wrote a letter so that four copies of the same letter were simultaneously produced.

Jefferson's stay in Paris (from August 1784 to September 1789) proved to be most influential on him. These five years constituted a creative period in his life. In Paris, Jefferson was exposed to a multitude of written sources that he had never seen before and a host of intellectual luminaries. Most of his inventions, in their original form or in his improved versions, he would take with him to the United States at the end of his term in Paris.

Back in the United States, while he was secretary of state, he served on the Board of Arts that dealt with patent applications. The forerunner of what later became known as the U.S. Patent Office, it came into existence in 1790. Jefferson was on a three-member commission and acted as the first patent commissioner and the first patent examiner. He personally reviewed every application submitted from 1790 to 1793, which allowed him to keep up to date with the latest developments. Jefferson established strict criteria for granting a patent, which included utility, novelty, and creativity.

Curiously enough, in the light of his role, Jefferson disliked patents because he thought that they went against democracy in that they prevented the population as a whole from enjoying a given invention. While he accepted that inventors might make a profit from their creations, he was against creations having restricted use. However, in time, he came to slightly revise his views on these matters, because he understood that patents encouraged people to invent, since they stood to make a profit. Nonetheless, he took no patents on any of his own inventions. As Jefferson was in favor of the dissemination of information, he was also against having a patent covering all the potential, future uses of a product.

Given Jefferson's lifelong interest in agriculture, which he considered a vital science, it is only natural that he devoted much of his inventing zeal to the improvement of farming machinery and utensils.

Along with his son-in-law Thomas Mann Randolph, around 1794, Jefferson developed a board plow. Jefferson had been toying with his idea of a new, improved plow while he was in France. Already in 1788, he had some ideas about having a moldboard made of wood. The first unit was used on his estate at Monticello, in Virginia, in 1794. Jefferson claimed that it was "mathematically demonstrated to be perfect" and, committed as he was to letting humanity as a whole profit from an invention, he found pride in the fact that it could be reproduced by anyone. The growing popularity of iron moldboards prevented the widespread use of Jefferson's plow, although he had his moldboard made of iron from 1814 onward. James Mease's *Domestic Encyclopedia* (first published in 1803) included it.

Jefferson introduced the pedometer in America following his stay in France, although it is not known if he brought with him the original article or if he improved it and therefore introduced his own version of it. The pedometer, also known as the "Tomish meter" after Jefferson, was based on an idea of Leonardo da Vinci and used the movement of the pendulum. It was rudimentary and prone to error, though, as it provided an estimate rather than an accurate figure. Jefferson's love for books led him to develop a bookstand for holding up to five books.

Jefferson also turned his attention to interior designing and, thus, in Monticello, there were no bedsteads. Instead, beds were placed in alcoves between pairs of rooms so as to use space as effectively as possible. Jefferson improved the revolving Windsor chair too, an example of which can be still seen at Monticello. Committed to making daily tasks easier so that they would not be so time-consuming, Jefferson also turned his attention to home economics and domestic matters, as his invention of household items testifies to. For instance, he developed a new system of dumbwaiters—pipes in his Monticello home that allowed his servants to send wine bottles upward from the basement cellar to the dining room. Jefferson also designed automatic double doors in Monticello in 1804. The unique, in-floor mechanism made both doors open or close at the same time.

His inventions earned Jefferson international recognition. Among other things, his interest in agricultural improvement won Jefferson the gold medal of

the French Society of Agriculture as well as being offered an honorary membership from this institution and the British Board of Agriculture (1797). The Agricultural Society in Florence also granted him an honorary degree.

Jefferson greatly contributed to American natural history when he promoted the Lewis and Clark Expedition. The expedition, the first of its kind to cross the western United States and territories, ostensibly sought a Northwest Passage, or a waterway that led all the way across the continent. Though the expedition found no such passageway, it did catalog hundreds of native plants and animals, map new territory, and establish an American claim to land that belonged to the native people who lived on it. The expedition provided invaluable scientific information.

Benjamin H. Latrobe and Jefferson created a sundial in 1809, but Jefferson also designed the Great Clock at Monticello's entrance although Louis Leschot built it. After the clock was built, Jefferson invented a special folding ladder that, from the beginning of the 19th century onward, has been very useful in libraries all over the United States.

So large and complex is Jefferson's invention library that inventions other than his own are sometimes wrongly attributed to him. Thus, in popular culture, Jefferson is sometimes credited as the inventor of such a common American dish as "mac and cheese," although this is a fallacy. Jefferson did work on a pasta machine, though, based on one he had brought with him from France, where, during his service as U.S. ambassador, he found that macaroni was a very fashionable dish in Parisian society. Jefferson came to see development and technological progress as crucial to the development of the new nation. Jefferson was strict in granting new patents and ruled out applications in which the only difference with existing patents was a slight change or a new material used to produce the item in question.

Despite the fame that Jefferson received in his lifetime for his contribution to scientific progress, more recently his status as inventor has been questioned. Some claim that the label "inventor" is not accurately attached to Jefferson, as rather than invent, he improved already-existing products. For them, the term that better applies to Jefferson is "innovator" rather than "inventor."

Thomas Jefferson died on July 4, 1836, at his home in Monticello. He is buried there. His tombstone lists his many accomplishments but does not mention his passion for innovation and invention.

M. Carmen Gomez-Galisteo

See also Lewis and Clark Expedition; Patent and Copyright Statutes; Swivel Chair; Three-Piece Iron Plow; Wheel Cipher

Further Reading

- Benson, G. Randolph. 1971. *Thomas Jefferson as Social Scientist*. Cranbury, NJ: Fairleigh Dickinson University Press.
- Cohen, Bernard. 1995. *Science and the Founding Fathers: Science in the Political Thought of Thomas Jefferson, Benjamin Franklin, John Adams and James Madison*. New York: W. W. Norton.
- Ellis, Joseph J. 1996. *American Sphinx: The Character of Thomas Jefferson*. New York: Alfred A. Knopf.

Lewis and Clark Expedition (1804–1806)

In 1803, President Thomas Jefferson asked Congress for money to fund a "Corps of Discovery." His intent was for a military team to explore and map the vast new Louisiana Purchase territory that the fledgling United States had just acquired. One of his top priorities was for the expedition to find an all-water route from mid-America to the Pacific, with rivers and a newly burgeoning canal system being essentially the "superhighways" of early America for transporting goods and people. By carrying the American flag overland to the Pacific Ocean, Jefferson also wanted the team to establish U.S. sovereignty over the Western territory and to establish trade agreements with indigenous people for the United States rather than the British, French, and Spanish.

However, under the watchful eyes of England, France and Spain, as well as Congress, Jefferson presented the goal of the Corps of Discovery in a somewhat different light. It was to be a scientific expedition in which Lewis and Clark would meticulously record observations about the animals, plants, geography, topography, and inhabitants of the virtually-unknown-to-Europeans territory through which they passed.

In addition to its extensive length, the scientific aspect would set Lewis and Clark's Corps of Discovery apart from previous explorations such as those by Robert de La Salle (1643–1687) as well as expeditions by contemporaries such as Zebulon Pike (1779–1813), in which scientific discoveries were not a priority.

In keeping with his scientific slant, Jefferson selected Army Captain Meriwether Lewis because of his vast knowledge of botany, natural history, mineralogy, and astronomy. Lewis then chose William Clark as second in command. With Jefferson's encouragement and patronage, the team leaders adopted the scientific method in preparing for the journey. Jefferson sent Lewis to Philadelphia to study medicinal cures under physician Benjamin Rush. The president also arranged for Lewis to be tutored by astronomer Andrew Ellicott in the use of the sextant and other means of utilizing the celestial bodies as navigational aids. Jefferson gave Lewis full access to his home library at Monticello, where Jefferson possessed what was said to be the world's largest library on the geography of North America.

Through the American Philosophical Society in Philadelphia, an expedition sponsor, Lewis and Clark received additional instruction in astronomy, botany, climatology, ethnology, geography, meteorology, mineralogy, ornithology, and zoology. All would come in handy during the expedition, where they would make contact with more than 70 tribes of Native American people and would go on to describe over 200 new plant and animal species.

After enlisting a team of 38 military men plus a few French boatmen and Lewis's dog, the voyage of discovery departed from St. Charles, Missouri, near St. Louis, on May 14, 1804. Sometimes moving up to 70 or 80 miles a day, the Lewis and Clark expedition would ultimately cover a grueling 8,000 miles over 28 months between 1804 and 1806.

Lewis and Clark began making detailed reports on what they encountered along their way West. They took scientific measurements and observations of the Missouri River, including its depth, current, and tributaries along with the inhabitants, plants, and wildlife to be found along its course. They would also go on to document their observations of the Rocky Mountains and the landscape of the Pacific Northwest.

Ultimately, Lewis and Clark's scientific observations would include descriptions of around 120 birds, fish, mammals, and reptiles. Soon after they departed, in what is today's Osage County, Missouri, they encountered and described their first animal that was then unknown to European science: the eastern wood rat. Other new animal species they encountered included bighorn sheep, black-tailed deer (or mule deer), buffalo, coyote, mountain beaver, mountain goats, pronghorn antelopes, white weasels, and various species of fox, rabbit, squirrel, wolf, and grizzly bears. The grizzlies became a topic of special note when the fierce animals attacked the group and were so tough that even several rifle shots were unable to kill them. The team recorded encountering so many buffalo that at one point that they had to club them out of the way. Lewis and Clark became fascinated with the prairie dogs that built huge underground villages and tended to outwit the humans who tried to trap them.

Lewis and Clark did not limit themselves to description. Shooting or otherwise catching an individual of each species of wildlife, they measured and described the specimen and then preserved it for shipment back to President Jefferson. Their zoological specimens included live animals as well as bones, horns, skeletons, skins, talons, and teeth. Among the live animals Lewis sent to Jefferson was a barking squirrel, or black-tailed prairie dog, which lived out the rest of its days at the White House.

Jefferson directed Lewis and Clark to pay special attention to the soil and the types of vegetables produced in different areas and climates. He believed that having a greater botanical knowledge of the continent's bounty would contribute to the world's food supply and would determine which plants were beneficial to humans. At Monticello, Jefferson planted seeds from the Lewis and Clark expedition, including "Missouri hominy corn," which he cultivated and studied, later reporting that the Indian corn he grew was an excellent source of food.

The Corps of Discovery team described hundreds of plants that were new to it, with Lewis writing extensively about the botany of the Pacific Northwest during a winter encampment on the Columbia River. Several botanical specimens discovered by Lewis and Clark were named after them: the pink *Clarkia pulchella*,

also known as pinkfairies, and the white *Philadelphus lewisii*, or Lewis's mock orange (today the state flower of Idaho). Their discoveries also included the future state flowers of Oregon (the Oregon grape, also known as the holly-leaved barberry or *Mahonia aquifolium*) and Montana (bitterroot, or *Lewisia rediviva*), as well as the state grass of Montana (bluebunch wheatgrass, or *Agropyron spicatum*).

Lewis and Clark collected plant specimens, recording information on growth, habitat, and uses by Native Americans. Lewis especially showed a talent for observation and lyrical writing in his essay about camas, or quamash, an important food plant for the Nez Perce tribe. He carefully noted the plant's environment and physical structure along with a description of Nez Perce women harvesting and preparing the camas to play its role in the tribe's diet.

The observations and reports by Lewis and Clark formed the basis for the first major scientific publication to describe and illustrate plant life west of the Mississippi River. They also collected plant samples and pressed them. The botanical specimens that Lewis and Clark sent back east were housed at the American Philosophical Society in Philadelphia, later finding a permanent home at Philadelphia's Academy of Natural Sciences, where their plant collection still exists today.

The Lewis and Clark team also made the first known attempt at a scientifically systematic record of the meteorology of the American West. In addition, they attempted to determine the latitude and longitude of significant geographical points. They determined the true course of the Upper Missouri River and its major tributaries. They disproved the prevailing theory that only a short portage separated it from the Columbia River, and they also found that the Columbia was hardly the short coastal river it was thought to be but a significant waterway similar to the Missouri itself. Lewis and Clark also discovered that neither the Missouri nor the Columbia was navigable to its source, as many believed they were at the time.

The expedition observed and recorded geological findings such as types of rock formations. In a discovery of great significance, they found through personal experience that neither the Rocky Mountains nor the Cascades were small, easily crossed mountain ranges

as was believed at the time. The discovery that the Rockies and Cascades were major barriers would modify the prevailing concept about how the American West would be traveled and settled.

For the most part, Lewis and Clark's team passed through country that no European Americans had yet seen. Clark, with some experience via army mapping and surveying, made a major scientific contribution in the field of cartography. The maps that he and Lewis created, though relatively crude, greatly enriched geographical knowledge of the western United States and would go on to stimulate advances in mapmaking. Their maps included names of streams and natural features. They also provided the first accurate description of the Rocky Mountains as well as the sources of the Columbia and Missouri Rivers. They were the first European Americans to cross the Continental Divide and to experience the grandeur of Yellowstone.

Yet for all their contributions to the "hard" sciences, one noteworthy aspect of the Lewis and Clark expedition is an intriguing footnote to the social sciences. An African American slave named York (1770–1831) and a Shoshone woman named Sacagawea (1788–1812) also accompanied the Corps of Discovery. On November 24, 1805, when the expedition reached the spot where the Columbia River emptied into the Pacific Ocean, Lewis and Clark held a vote among all the members of the group to decide where to settle for the winter. Both Sacagawea and York were permitted to vote, with their votes counting equally among those of the others. It was the first and only known instance of a woman and an African American having the opportunity to vote in the United States and would remain so for the better part of a century.

Nancy Hendricks

See also Canals; Rush, Benjamin; *Vol. 1, Sec. 3: Equatorial Sextant*

Further Reading

- Ambrose, Stephen. 1997. *Undaunted Courage: Meriwether Lewis, Thomas Jefferson, and the Opening of the American West*. New York: Simon & Schuster.
- Lewis, Meriwether, and William Clark. 1997. *The Journals of Lewis and Clark*. Edited by Bernard DeVoto. New York: Houghton Mifflin.

Primary Document: Excerpts from the Journal of the Lewis and Clark Expedition (1805, 1806)

The first excerpt here is from Meriwether Lewis's expedition journal from May 1, 1805. The expedition was heading west from Fort Mandan to the Pacific and by May had made it to present-day Montana. Lewis recorded a variety of subjects in his journal, including meticulous examinations of new species of animals. The following is a description of a waterbird from the Milk River. The second excerpt is from the trip home from the Pacific back through Montana and describes a ground squirrel.

May 1st 1805.
Shannon killed a bird of the plover kind the weight one pound.—eye black percing and prominent [EC: avocet (*Recurvirostra*)]

Measure	F.	Inchs
from the tip of the toe to the extremity of the beak	1	10
from tip to tip of wing when extended	2	5
length of beak		3 ⁵ / ₈
length of tale		3 ¹ / ₈
length of leg (thy,) and toe		10

the legs are flat, of pale skye blue colour and but slightly imbricated. the second joint, as low as the mustle extends is covered with feathers which is about half it's length. it has three toes on a foot connected by a web. there is also a small toe on each foot placed about the eighth of an inch up the leg behind. the nails are black and short and those of the middle toes ar singular—there being two nails on each the one above the other the upper one the longest and sharpest.— the tale contains eleven feathers of the same length of a bluish white colour. the body and under side of the wings except the large feathers of the 1 & 2cd joints of the wings are white, as are also the feathers of the upper part of the 4th joint of the wing. and some of those of the 3rd adjoining.— the large feathers of the pinion or first (joint) & the second joint (and a part of those of the third on the) are black; a part of the larger feathers of the third-joint on the upper side and all the smaller feathers which cover the upper part of these joints ar black; as

are also the tuft of long feathers on each side of the body above the joining of the wing, leaving however a stripe of white between them on the back. the head and neck are shaped much like the grey plover, and is a light (yellowish) brickdust brown. the beak is black and flat, largest where it joins the head and from thence tapering every way gradually to a very sharp point the upper beak being ¹/₈ of an inch the longest turning down at the point. the nostrils are parrallal with the beak and are long narrow and connected. the beak is curved and invirted; the Curvature being upwards in stead of downwards as those of most birds are—the substance of the beak is as flexible as whalebone and (to all appe) at a little distance precisely resembles that substance. their note is like that of the common whistling or grey plover tho' reather louder, and more varied, and their habits are the same with that bird so far as I have been enabled to learn, with this difference however that this bird sometimes lights in the water and swims.—it generally feads about the shallow bars of the river; to collect it's food, it immerces it's beak in the water, and thows it's head and beak from side to side at every step it takes.

Tuesday July 1st 1806.

The little animal found in the plains of the Missouri which I have called the *barking squirrel* weighs from 3 to 3½ pounds. it's form is that of the squirrel. it's colour is an uniform light brick red grey, the red reather predominating. the under side of the neck and bely are lighter coloured than the other parts of the body. the legs are short, and it is wide across the breast and sholders in proportion to it's size, appears strongly formed in that part; the head is also bony muscular and stout, reather more blontly terminated wider and flatter than the common squirrel. the upper lip is split or divided to the nose. the ears are short and lie close to the head, having the appearance of being cut off, in this particular they resemble the guinea pig. the teeth are like those of the squrrel rat &c. they have a false jaw or pocket between the skin and the mustle of the jaw like that of the common ground squrrel but not so large in proportion to

their size. they have large and full whiskers on each side of the nose, a few long hairs of the same kind on each jaw and over the eyes. the eye is small and black. they have five toes on each foot of which the two outer toes on each foot are much shoter than those in the center particularly the two inner toes of the fore feet, the toes of the fore feet are remarkably long and sharp and seem well adapted to cratching or burrowing those of the hind feet are neither as long or sharp as the former; the nails are black. the hair of this animal is about as long and equally as course as that of the common grey squirrel of our country, and the hair of the tail is not longer than that of the body except immediately at the extremity where it is somewhat longer and frequently of a dark brown colour. the part of generation in the female is placed on the lower region of the belly between the hinder legs so far forward that she must lie on her back to copolate. the whole length of this animal is one foot five inches from the extremity of the nose to that of the tail of which the tail occupyes 4 inches. it is nearly double the size of the whistling squirrel of the Columbia. it is much more quick active and fleet than it's form would indicate. these squirrels burrow in the ground in the open plains usually at a considerable distance from the water yet are never seen at any distance from their burrows. six or eight usually reside in one burrow to which there is never more

than one entrance. these burrows are of great debth. I once dug and pursued a burrow to the debth of ten feet and did not reach it's greatest debth. they generally associate in large societies placing their burrows near each other and frequently occupy in this manner several hundred acres of land. when at rest above ground their position is generally erect on their hinder feet and rump; thus they will generally set and bark at you as you approach them, their note being much that of the little toy dogs, their yelps are in quick succession and at each they a motion to their tails upwards. they feed on the grass and weeds within the limits of their village which they never appear to exceed on any occasion. as they are usually numerous they keep the grass and weeds within their district very closely grazed and as clean as if it had been swept. the earth which they throw out of their burrows is usually formed into a conic mound around the entrance. this little animal is frequently very fat and it's flesh is not unpleasant. as soon as the hard frosts commence it shuts up it's burrow and continues within untill spring. it will eat grain or meat.

Source: Lewis, Meriwether and William Clark. 1904, 1905. *Original Journals of the Lewis and Clark Expedition*. Volume 1 and Volume 5. Edited by Reuben Gold Thwaites, 357–58 (V1), 177–78 (V5). New York: Dodd, Mead & Company.

Lobster Trap

Ebenezer Thorndike of Swampscott, Massachusetts, invented the lobster trap in about 1808 as a practical way to catch lobsters. His revolutionary wooden trap allowed fishermen to lower it onto the sea floor. A rope extending from the trap to the water's surface connected it to a buoy with the fisherman's identification. The bread-box-size trap had a one-way, funnel-shaped entrance called a "door." It allowed the lobster to enter the trap but not exit it.

Lobster traps today generally have two compartments. The first compartment, known as the "kitchen," lures the lobster inside with a hanging, fish-filled mesh bag. The funnel-shaped entrance prevents the lobster from retreating once it eats the bait. Cornered, it climbs into the second compartment known as the "parlor." It

remains there until the fisherman retrieves it. Modern lobster traps have escape vents for undersized lobsters and biodegradable escape hatches in case an occupied trap becomes lost. The lobster trap remains in almost the same configuration as when Thorndike invented it, except the wood has been replaced with metal wire to ensure a lighter-weight, easily stackable contraption that does not erode in salt water.

Amy Helene Forss

See also *Vol. 1, Sec. 1: Schooner*; *Vol. 1, Sec. 3: Floating Dry Dock*

Further Reading

White, Christopher. 2018. *The Last Lobster: Boom or Bust for Maine's Greatest Fishery?* New York: St. Martin's Press.

Lowell Mill System

Prior to the Industrial Revolution (1820–1870), textiles were produced in the home. With the advent of industrialization, however, home production dwindled and textiles began to be produced largely by factories. In 1826, several factory owners purchased Chelmsford, Massachusetts, as the site for a manufacturing town. This portion of Chelmsford was renamed Lowell after Francis Cabot Lowell (1775–1817), an American businessman who improved American spinning and weaving machines and founded the first mill in America where raw cotton was processed and converted into cloth in the same building. Lowell, Massachusetts, is significant to the history of American industrialization because the town was entirely based around mill life. The mills employed primarily female workers, who lived in local boarding houses, shopped at company stores, and engaged in company-approved leisure-time activities, making Lowell the first company town.

The Lowell mill system was unique in that it purposefully hired young women, both because women were paid less and because young men were still

working on family farms in the early 1800s. Women workers came from New England farms and were between the ages of 15 and 25. Many came to the mills to help support their families or to send their brothers to college. Most women signed up for short terms of employment, averaging three years, and left to marry, return home, or emigrate west. During the 1850s, Lowell factory owners began hiring female Irish immigrants who had fled to the United States to escape the Irish Potato Famine (1845–1851).

By 1836, Lowell was the home to over 17,000 people, most of whom were female mill workers. Work began at 5:00 a.m. and ended at 7:00 p.m., with two breaks lasting a half hour each. In 1834, the company announced it would cut wages. Women workers took to the streets in protest. Though the strike did not raise wages, it did provide female workers with strike experience. In 1836, owners once again announced that wages would be cut. Also, workers would pay housing and meals, which had previously been partially paid for by the factory, in full. Factory workers again went on strike. Mills were forced to shut down, and between 1,200 and 1,500 women and girls marched through town in protest, singing songs as



The women who worked in the Lowell Mills in the early 19th century were America's first factory workers. The Lowell Mill System included spinning, weaving, and dyeing factories, as well as housing, religious services, and entertainment for "lady operatives." (Library of Congress)

they walked. At a time when women rarely spoke in public, Lowell women made speeches against their employers' decision to reduce wages.

Skilled factory laborers led the landmark 1836 strike. Workers had correctly assumed that if the most central workers in the factory walked out, it would be forced to close. The strike lasted for two weeks, and the Factory Girls' Association was founded with 2,500 members. The Association's constitution maintained that any woman who worked in the mills and had a good reputation could join the association. Similar to a labor union, the Factory Girls' Association demanded better conditions for its members. Key to its demands was that factory owners not punish members of the Factory Girls' Association. The 1836 strike concluded with little significant change in worker's conditions, but the factory owners agreed to continue paying a partial fee for lodging.

In 1845, factory workers were still fighting for fair wages and board. Recognizing that the Factory Girls' Association was not strong enough to address these issues, in January 1845, 12 factory workers organized the Lowell Female Labor Reform Association (LFLRA), the first union of working women in the

United States. Like the Factory Girls' Association, the LFLRA campaigned to protect workers' wages and for the 10-hour workday. Within six months, membership had grown to 500. Both the Factory Girls' Association and the LFLRA served notice to factory owners that their female workforce would be neither passive nor submissive about its rights as workers. In the 1840s and 1850s, female unions would spread to factory towns in Manchester, Massachusetts; Dover, New Hampshire; and Fall River, Massachusetts.

Laura J. Ping

See also Milling Machine; *Vol. 1, Sec. 1: Loom*

Further Reading

- Foner, Philip S. 1977. *The Factory Girls*. Chicago: University of Illinois Press.
- Robinson, Harriet H. 1976. *Loom and Spindle or Life among the Early Mill Girls*. Kailua, HI: Press Pacifica.
- Zonderman, David A. 1992. *Aspirations and Anxieties: New England Workers and the Mechanized Factory System, 1815–1850*. New York: Oxford University Press.

Primary Document: Description of the Life of a Mill Girl from the Lowell Offering (1845)

The following is an anonymously authored description of the life of a Lowell Mill girl, first published in volume V of the Lowell Offering in 1845. The reality of cotton mill work fell well short of the propaganda generated by mill owners, which portrayed mill work as wholesome, safe, and generally pleasant.

Much has been said of the factory girl and her employment. By some she has been represented as dwelling in a sort of brick-and-mortar paradise, having little to occupy thought save the weaving of gay and romantic fancies, while the spindle or the wheel flies obediently beneath her glance. Others have deemed her a mere servile drudge, chained to her labor by almost as strong a power as that which holds a bondman in his fetters; and, indeed, some have already given her the title of "*the white slave of the*

North." Her real situation approaches neither one nor the other of these extremes. Her occupation is as laborious as that of almost any female who earns her own living, while it has also its sunny spots and its cheerful intervals, which make her hard labor seem comparatively pleasant and easy.

Look at her as she commences her weekly task. The rest of the sabbath has made her heart and her step light, and she is early at her accustomed place, awaiting the starting of the machinery. Every thing having been cleaned and neatly arranged on the Saturday night, she has less to occupy her on Monday than on other days; and you may see her leaning from the window to watch the glitter of the sunrise on the water, or looking away at the distant forests and fields, while memory wanders to her beloved country home; or, it may be that she is conversing

with a sister-laborer near; returning at regular intervals to see that her work is in order.

Soon the breakfast bell rings; in a moment the whirling wheels are stopped, and she hastens to join the throng which is pouring through the open gate. At the table she mingles with a various group. Each despatches the meal hurriedly, though not often in silence; and if, as is sometimes the case, the rules of politeness are not punctiliously observed by all, the excuse of some lively country girl would be, "They don't give us time for *manners*."

The short half-hour is soon over; the bell rings again; and now our factory girl feels that she has commenced her day's work in earnest. The time is often apt to drag heavily till the dinner hour arrives. Perhaps some part of the work becomes deranged and stops; the constant friction causes a belt of leather to burst into a flame; a stranger visits the room, and scans the features and dress of its inmates inquiringly; and there is little else to break the monotony. The afternoon passes in much the same manner. Now and then she mingles with a knot of busy talkers who have collected to discuss some new occurrence, or holds pleasant converse with some intelligent and agreeable friend, whose acquaintance she has formed since her factory life commenced; but much of the time she is left to her own thoughts. While at

her work, the clattering and rumbling around her prevent any other noise from her attention, and she *must think*, or her life would be dull indeed.

Thus the day passes on, and evening comes; the time which she feels to be exclusively her own. How much is done in the three short hours from seven to ten o'clock. She has a new dress to finish; a call to make on some distant corporation; a meeting to attend; there is a lecture or a concert at some one of the public halls, and the attendance will be thin if she and her associates are not present; or, if nothing more imperative demands her time, she takes a stroll through the street or to the river with some of her mates, or sits down at home to peruse a new book. At ten o'clock all is still for the night.

The clang of the early bell awakes her to another day, very nearly the counterpart of the one which preceded it. And so the week rolls on, in the same routine, till Saturday comes. Saturday! the welcome sound! She busies herself to remove every particle of cotton and dust from her frame or looms, cheering herself meanwhile with sweet thoughts of the coming sabbath; and when, at an earlier hour than usual, the mill is stopped, it looks almost beautiful in its neatness.

Source: Anonymous. 1845. "A Week in the Mill." *Lowell Offering*, V: 217–18.

Milling Machine

Eli Whitney is best known for his invention of the cotton gin, but for many years and in many circles, he also was credited with inventing the milling machine. However, while the noted machine tool historian Joseph W. Roe has credited Whitney with inventing the first milling machine around 1818, many subsequent historians acknowledge that while Whitney was an important figure in the development of the milling machine, there is sufficient evidence to indicate that a number of inventors were working on the concept at the same time. Thus, it is difficult to give Whitney exclusive or full credit. More likely, he belongs in the group of inventive figures who composed, however informally and unconsciously, a collaborative network that in the end produced the important machine.

A milling machine is essentially a form of metal-cutting machine. The kind of work it was subsequently developed to do was at the heart of the individual handmade process that characterized the efforts of early craftsman. Indeed, before the machine was developed, a craftsman would have to individually cut each metal piece to the proper size and configuration, and then the edges would have to be smoothed before assembly—of whatever the final product might have been—could be undertaken. This long and laborious task was part of the reason it took so long for handmade products to be completed, as well as why each was so distinctive.

In contrast to this individualized, labor-intensive process, the milling machine was a device similar to a lathe in that it featured a rotating cutting tool that allowed a machinist to produce a succession of almost

identical items. This left the skilled craftsman with only the comparatively smaller task of smoothing with a file the edges of each individual piece, a process that was still needed to provide a form of polish. This new approach made the process both easier and faster than when the work had been done by the individual operators, who themselves needed to be more technically skilled than the laborer who would now operate the milling machine. In addition, the milling machine allowed for the creation of a series of pieces all the same basic size. In fact, in the early years of their operation, the milling machine was hailed for the way it reduced subsequent hand filing while also bringing a consistency to the size and shape of the pieces. Indeed, the machine's capabilities fit right in with the broader efforts that Whitney and others were developing in regard to interchangeable parts. While the milling machine's development lagged behind the efforts of those working with interchangeable parts, the ultimate development of the milling machine would help further the whole mass production effort fueled by the development of interchangeable parts.

As to the matter of credit, machine tool historian Joseph W. Roe is the man most responsible for tapping Whitney as the inventor of the milling machine. Relying largely on the famous Whitney Machine, an invention initially believed to have been created in 1818, he pronounced Whitney the “father of the milling machine.” However, later work by historians, including Robert Woodbury, Merritt Roe Smith, and Edwin Battison, point to a wider-ranging effort, one that places Whitney among a group of fellow inventors, all of whom were going in the same direction and working toward the same end. At the same time, it is distinctly possible that Whitney's outsized reputation as the inventor of the cotton gin, a major force behind the development of interchangeable parts, not to mention being nationally renowned as the man who, in the words of his benefactor, Mrs. Nathanael Greene, “could fix anything,” coupled with his well-established skills as a salesman and marketer, served to overshadow the efforts of others.

In the end, enough questions exist—including whether the model on which Roe has based his determination, and which was supposedly built in 1818, was even built in that year—and enough counterevidence

has been uncovered to make clear that while Whitney played an important and substantive role in the development of this important machine, neither he nor anyone else can truly claim the mantle of sole inventor of the technological advance that the milling machine represented.

William H. Pruden III

See also Whitney, Eli

Further Reading

Battison, Edwin A. 1973. “A New Look at the ‘Whitney’ Milling Machine.” *Technology and Culture* 14, no. 4 (October): 592–98.

Green, Constance McL. 1956. *Eli Whitney and the Birth of American Technology*. Boston: Little, Brown.

Morey, Samuel (1762–1843)

An American inventor and engineer, Samuel Morey acquired over 20 patents in his lifetime. His most notable work was done on two types of engines: the steam engine and the internal combustion engine. However, Morey received little recognition for his innovations. His design of what he called a “vapor engine” is considered one of the first internal combustion engines. Upon creating his first functional vapor engine, he predicted that travel could, in the very near future, be made faster and cheaper. Morey also performed many experiments using a variety of materials for combustion, including pumpkin, oils, coal, rosin, and many seeds. The records of these experiments proved useful to pure scientists such as Gay-Lussac, the well-known chemist.

In 1793, Morey received his first patent for a steam-powered spit that would mechanically rotate rotisserie food, using steam power as it cooked. Because his father owned a ferry, Morey saw the benefits of a steam-powered boat. In the early 1700s, Jonathan Hull had already attempted steam-powered watercraft, but his experiments failed. Like they did at many revolutionary ideas, people laughed at the idea of using steam to propel boats, but Morey predicted its success and set to work. His first boat utilized a

forward-mounted paddle wheel and a steam-powered engine. Using this, he successfully made trips up and down the Connecticut River, showing that the concept was credible. Eventually, Morey designed a boat that made use of two side-mounted paddles. Under steam power, the boat could attain speeds of four miles per hour. Confident in his design, he sought investors but had little success. Robert Livingston originally offered a significant amount of money if Morey could double his boat's speed; however, in the end, his money went to one Robert Fulton (whom Morey claims stole aspects of his design).

Morey abandoned the steam engine in favor of his vapor engine idea. Upon discovering the potential of combusting turpentine, he designed an engine with two cylinders, valves, cams, and a carburetor similar to modern-day internal combustion engines. The main difference in his vapor engine is that the combustion wasn't the direct source of power; it had a more complex and convoluted design, causing it to be less efficient. However, this didn't stop Morey from exhibiting this engine in the first American automobile ride.

Samuel Morey died in 1843 and was buried in Fairlee, Vermont. Although neither his steamboat nor his internal combustion engine were used commercially or given much credit in his day, his work has garnered him the attention of historians of science and technology.

Kalan Small

See also Amphibious Steam Vehicle; Fulton, Robert; High-Pressure Steam Engine; Internal Combustion Engine; Steamboat; *Vol. 1, Sec. 3: Steam Locomotive*

Further Reading

Carter, George Calvin. 1945. *Samuel Morey: The Edison of His Day*. Concord, NH: Rumford Press.

Maurer, Leon. "The Unsolved Mystery of Samuel Morey." Creative Commons. <https://www.google.com/search?q=Maurer%2C+Leon.+%E2%80%99CThe+Unsolved+Mystery+of+Samuel+Morey.+Creative+Commons.&aq=chrome.69i57.520j0j7&sourceid=chrome&ie=UTF-8>, accessed September 12, 2018.

Multitubular Boiler

The multitubular boiler was created by Nathan Read in 1788. Its main purpose was to sustain higher pressure within a steam engine. The boiler is thus essential to steam engine operation.

Multitubular or locomotive-type boilers operate when fuel is burned in a firebox to create heat; the firebox is surrounded by a jacket of water tubes and connected to a boiler shell. Heated gas from the fire tubes create saturated or "wet" steam, which rises and is collected in a steam dome. This steam is then directed into the engine's cylinders or turbines to create mechanical work. Excess gas is generally let out through a chimney. The multitubular boiler represents an improvement on earlier boilers because it used large numbers of small tubes, thereby increasing heat transfer and significantly improving the rapidity of steam production.

These boilers came in both horizontal and vertical types. Modern steam engines have added a number of improvements to the 19th-century boiler design, making the engines much safer and more efficient. Boiler explosions, which used to kill hundreds and even thousands of people each, are now prevented with safety valves and fusible plugs.

Jonathan A. Escobar

See also Steam Engine; Steamboat

Further Reading

Ganapathy, V. 2015. *Steam Generators and Waste Heat Boilers: For Process and Plant Engineers*. Boca Raton, FL: CRC.

National Road

At the dawn of the 19th century, the biggest barrier to the progress of the nation was the lack of a transportation system connecting the East Coast to the then western frontier. There was no water connection, as the Allegheny Mountains separated the Potomac and Ohio Rivers. Lack of transportation limited the growth of western industry and agriculture. Following an old Indian trail, George Washington had been one of the



The National Road, also known as the Cumberland Road, just outside Brownsville, Pennsylvania, in 1910. Built between 1811 and 1837, the road was a main route for settlers traveling West. (Library of Congress)

first settlers to make the portage between the Potomac and Ohio Rivers as a young surveyor in 1753. The path was known as Nemacolin's Trail after the Delaware Indian chief. The trail connected Maryland and Pennsylvania via the Cumberland Gap in the mountains. A few years later, Washington helped build a rough road along this trail for General Braddock's failed expedition to take the headwaters of the Ohio (present-day Pittsburgh) from the French. The trail, known as Braddock's Road (today's Route 40), and its competing trail, known as Boone's Trail, were the only paths west at the start of the 1800s. Forbes Road was a longer trip that went through Pennsylvania to Philadelphia.

One of America's first highways in the 1730s was known as "the Great Philadelphia Wagon Road." German and Swiss families set up a transportation network between Philadelphia and Lancaster to support the extensive trade. The road was built privately on the

belief that it would foster trade and wealth. It was America's first toll road. This first turnpike allowed German farmers to become wealthy, supplying both Philadelphia and Lancaster. The rise of capitalism surrounding the turnpike rivaled that of the shipping ports of New England. At the western terminus of the road, German craftsmen developed the Conestoga wagon, also called the "prairie schooner." These giant freight wagons were named after Conestoga Creek at Lancaster. They were watertight and used iron belts around their wooden wheels as tires. Six- to eight-horse teams pulled these freight wagons. They moved in convoys of up to 100. By the 1740s, around 10,000 Conestoga wagons were in use. The Germans went into breeding "Conestoga" horses to further improve the overall transportation system. Lancaster not only moved farm products to Philadelphia but also gathered furs and whiskey from the western frontier for shipment to Philadelphia and on to Europe. The turnpike became a

vital link in the Scotch-Irish trading network of furs, whiskey, tobacco, ginseng, and grain. Philadelphia became the nation's major port because of this turnpike. The word "turnpike" came from the use of wooden pikes to mark turns and direction. This turnpike played a key role in the development of whiskey production in western Pennsylvania. In the early 1800s, Federalists were calling for a national road.

In 1794, the federal army was sent on the old Braddock Road through the Cumberland Gap to put down the Whiskey Rebellion. Sinkholes, poor drainage, and old stumps slowed the army. Ironically, Albert Gallatin, a participant in the Whiskey Rebellion, became the National Road's biggest supporter as Thomas Jefferson's secretary of the Treasury. In 1806, a bill was introduced by Kentucky congressman Henry Clay to build a road through the Cumberland Gap to connect the Ohio River to the East. More than anybody, Clay was weary of the monthlong trip from Lexington, Kentucky, on the Ohio River to Washington. Virginia and Maryland favored a road that would choose their ports over those of New York and Philadelphia. While Jefferson signed the bill in 1806, political arguing over the route continued. In 1811, Congress finally assigned contracts for the construction. Congress had also decided to bypass Pittsburgh, with the National Road going through Wheeling, a decision that was probably due in part to Pittsburgh's role in the Whiskey Rebellion.

Construction of the first leg of the road from Cumberland, Maryland, to Wheeling, West Virginia (130 miles), took six years. This first road had a 66-foot right-of-way with a 20-foot roadbed. It tapered from the centerline for drainage and at the center had 18 inches of crushed stone. Wages for road workers ranged from 12 to 80 cents a day. It was tough work through the Pennsylvania mountains, and many streams had to be crossed. Costs were as high as \$13,000 per mile in this difficult stretch. The first economic benefit was the use of the road for federal mail to the frontier. The early road was a combination of leveled earth and stone. In areas of heavier traffic, wooden planks were often used (many of these areas retain the name "plank" even today). In the 1820s, the road was resurfaced using a layer of crushed stone.

John Macadam invented the method, which became known as "macadamization."

The road progressed along the present Route 40 from Wheeling to Vandalia, Illinois. The Ohio portion from Wheeling followed "Zane's Trace," a federal horse path financed by the federal government back in the 1790s to increase trade. In 1834, Democratic President Andrew Jackson vetoed a bill from Clay, of the Whig Party, to extend the road again into his home state of Kentucky. In addition, Jackson turned most of the eastern part of the road over to the states. The states turned it into a toll road. Tollhouses were placed every 15 miles, and a toll of two to five cents was charged based on the type of cargo and estimated weight (a practice that still exists). In the 1830s, an express wagon could make 150 miles a day on the road. Average travel was slower, with nightly stops at major inns along the road.

The National Road advanced the fields of civil engineering, road building, and bridge building. Both the Federalists and the Democrats believed in the need for government involvement in building infrastructure but disagreed on who should pay for and maintain the roads. The main opposition to the road was based on regional politics because some sections of the country, like the South, had little benefit from it. New England opposed it because it strengthened more southerly ports such as Baltimore. In general, however, road building had strong support throughout America. The first accepted local taxes in America were for roads and schools. Tolls, however, proved less popular as travelers developed trails around tollgates known as "shunpikes." The success of the National Road to expand business made road building an important part of the emerging Whig Party, which was dedicated to the economic prosperity of America.

Quentin R. Skrabec

See also Erie Canal; *Report on Manufactures*

Further Reading

Raitz, Karl. 1996. *The National Road*. Baltimore: Johns Hopkins University Press.
Schneider, Norris. 1975. *The National Road: Main Street of America*. Columbus: Ohio Historical Society.

Odometer

Benjamin Franklin invented the three-wheel odometer in 1749 to measure the length of postal roads.

King George III appointed Franklin the postmaster of Philadelphia in 1737 and deputy postmaster general for North America in 1753. Given the fast growth of the British colonies in the 18th century, Franklin felt the necessity to improve the postal system to facilitate communication and trade. The mail service also needed to be upgraded. A high percentage of the mail was lost or stolen, and in other cases, it simply took too long.

Before Franklin's postal appointment, slaves, friends, and even sailors delivered letters from town to town on a voluntary basis. Post offices were set up in pubs and coffeehouses. Franklin wanted independent post offices throughout the colonies, and he needed to know how far they were apart so as to incorporate logistical efficiencies.

While the concept of the odometer dates back to ancient times, Franklin created a unique and much-improved version. The device registered the distance traveled when it was attached near the wheels of the carriage. Based on the circumference of the wheel and the number of revolutions required to travel a mile, the distance traveled could be calculated. When activated from a carriage wheel having a circumference of 13 and one-fifth feet, a mile was completed every 400 revolutions. If fixed to the top of the front axle at the right-hand side, it was easily set in operation by a nub-type projection on a hub or spoke, and the dials were readily detectible to both the driver and the passenger.

As noted above, the odometer consisted of a series of cogs and wheels that measured distance. On the top of the works was a flat metal plate that had a series of three circles. The left circle had a T above it and had numbers from 10 to 1 running counterclockwise around the circle, with "10" in the noon position. The circle was white with black Arabic numerals. At the center circle was a brass arrow—the one on the left was completely missing, and the one on the right was only a flat disk. The odometer was made of iron and brass and painted in light gold. It was one and two-thirds inches

in height, six and seven-eighths inches wide and four and one-quarter inches long.

By using the odometer to measure distances and creating other innovations in the postal system, Franklin was able to create a profit for the postal service by his fourth year in office. He was able to introduce night travel for postal riders, have mail delivered between Philadelphia and New York in a day, and have the reply come back the next day. Most important, these modernizations aided in significantly improving the mail service and integrating the distant regions of the colonies. It began the process of fortifying the strewn colonies into one unified country: the United States of America.

Abhijit Roy

See also *Vol. 1, Sec. 1*: Franklin, Benjamin

Further Reading

- Chapin, Joyce E. 2006. *The First Scientific American: Benjamin Franklin and the Pursuit of Genius*. New York: Basic Books.
- Flemming, Candace. 2003. *Ben Franklin's Almanac: Being a Good Account of the Good Gentleman's Life*. New York: Simon & Shuster.
- Talbott, Page, ed. 2005 *Benjamin Franklin: In Search of a Better World*. New Haven, CT: Yale University Press.

Patent and Copyright Statutes

It is amazing that the young nation of the United States put such emphasis on the protection of copyrights and patents. However, this focus would lead to America's greatest period of creativity and invention. Without the protection of intellectual rights, it is impossible for capitalism to flourish. Two of the Founding Fathers, Thomas Jefferson and Benjamin Franklin, attributed the growth of the nation to the spread of the useful arts. In 1783, as the Continental Congress considered the Articles of Confederation, a number of American authors, including Noah Webster, petitioned the Congress "that nothing is more properly a man's own than the fruit of his study, and that the protection and

security of literary property would greatly tend to encourage genius and to promote useful discoveries.” Jefferson, an inventor himself, took particular interest in copyright and patent law.

The colonies had had copyright and patent laws in place since the 1600s. Early colonial law was based on English law, which allowed for royal monopolies when the Crown chartered protection for the inventor; however, much of the profit would go to the Crown. The view was that inventions were the property of society, to be managed by a monarch. In the colonies, colonial courts could offer protection. The first colonial patent was issued to Joseph Jencks for the production of scythes in 1646. The General Court of Massachusetts chartered Jencks’s patent. In 1710, the Statute of Anne gave protection for a fixed period of usually 14 years. The Statute of Anne would become the basis for American patent and copyright law. Prior to 1790, the colonies and the states continued the practice of granting monopolies as a reward, but this actually reduced creativity. The state of New York, for example, gave John Fitch a steamboat monopoly in 1787 (but it would be repealed by federal law; see article 8 of the Constitution). Challenges to patents were possible but were debated among politicians as to their validity. Such a system favored the well known and wealthy. Most colonial inventors chose to keep their improvements secret rather than apply under a weakly enforced colony law.

At the Constitutional Convention of 1787, James Madison championed the need for federal protection versus protection by individual states. Intellectual property ownership was considered a basic right from our beginning as a nation. Copyright and patent law was authorized by the U.S. Constitution in Article I, Section 8, Clause 8, which states: “The Congress shall have the Power . . . To promote the progress of science and useful arts, by securing for limited times to Authors and Inventors the exclusive right to their respective writings and discoveries.” There was a debate between the Federalist James Madison and Jefferson. Jefferson wanted to encourage invention but feared the monopolies that might result from patents. Madison preferred unlimited periods of protection until the death of the inventor, while Jefferson argued

for a maximum of 14 years. This debate continues to this day.

In 1790, Congress passed the Copyright Act and the Patent Act. The Patent Act was meant to encourage creativity in the useful arts. These acts were unique in the world, offering an inventor for a time an intrinsic right to profit from his invention under protection of the law. It went far beyond British law, which had focused on the rights of society versus those of the inventor. British inventors’ rights were dependent on the prerogative of the monarch. American law now made the ownership of intellectual property an individual right. This was a break from English law that looked at invention as the property of society. It would inspire a wave of immigration by craftsmen and the European middle class to come to America as entrepreneurs. These American acts extended no protection to British copyrights, which allowed many machine- and toolmakers to bring their processes to America.

The Patent Act of 1790 named Secretary of State Thomas Jefferson as patent examiner. He proved a tough enforcer. Once reviewed, a patent received the signatures of the attorney general and the president. The inventor was charged a fee of around four dollars (a fairly large sum at the time). The first U.S. patent was given to Samuel Hopkins of Vermont for the improvement in the manufacture of potash (a necessary ingredient in soap and gunpowder). The duties of patent examiner soon overwhelmed Jefferson. The Patent Act, like the Copyright Act, allowed for protection for 14 years, with renewal possible for another 14 years. Another concern of Jefferson’s was the possibility of frivolous lawsuits preventing the use of improvements. In fact, Jefferson would be sued over one of his gristmill improvements and was forced to pay American superinventor Oliver Evans.

Jefferson was totally in charge of enforcing the new law. Jefferson demanded extensive proof that an invention was truly an improvement. He often demanded demonstrations and experiments as proof. He often requested the building of models to ensure the functioning of bigger projects. One example of his thoroughness was on the application of Jacob Isaac’s process for distilling freshwater from seawater. The idea was complex, and Jefferson appointed a board of scientists to review it. The board included famous American glassmaker Casper Wistar and astronomer

David Rittenhouse. Finally, after extensive testing, the patent was denied. The rigorous evaluation of patents made the American approach very unique in the world. Jefferson continued to improve the patent process. In 1793, the act was revised at his recommendation to establish a State Department clerk to aid in patent review. A full office of clerks was established in 1802. More so than any other person, Jefferson is responsible for American patent law and enforcement, which tries to balance individual rights, monopoly abuse, and the good of society. It was a unique balance that set the stage for a 200-year boom in American creativity. By the 1820s, the United States had issued 535 patents compared to 145 patents in England, which was the greatest industrial power on earth at the time.

Quentin R. Skrabec

See also Jefferson, Thomas; Steamboat

Further Reading

- Khan, Zorina. 2009. *The Democratization of Invention: Patent and Copyrights in American Economic Development*. Cambridge: Cambridge University Press.
- Pursell, Carroll. 1990. *Technology in America*. Cambridge, MA: MIT Press.
- Skrabec, Quentin. 2006. *The Metallurgic Age*. Jefferson, NC: McFarland.

Practical Ocean Navigation

Navigating the oceans in the 18th century was not easy. Contemporary navigation manuals contained inaccurate data. Methods to plot a ship's course were complicated and sometimes just educated guesses. Nathaniel Bowditch (1773–1838) was not a career sailor, but he used his mathematical expertise to correct inaccuracies in the primary manual of the day and to develop a navigational guidebook that relied on logarithms, logic, and accuracy.

When Bowditch was 10 years old, his family could not afford to continue to send him to school, so he worked for his father and studied on his own. He taught himself algebra and calculus and learned French and Latin so he could read advanced math books. Bowditch

became an apprentice clerk on a ship that sailed from Salem, Massachusetts, when he was 22 years old. While at sea for a year, he studied navigation.

The leading navigation manual at the time, *The New Practical Navigator* by John Hamilton Moore, was first published in 1772 in England. Bowditch studied the book's navigation tables and found many errors that could put a ship off course. While at sea, Bowditch corrected these mathematical miscalculations.

The American printer of *The New Practical Navigator*, Edmund Blunt (1770–1862), published an edition with those corrections. He decided that there were so many changes, he would publish a new edition of the book with corrected charts and navigation tables as well as information that American sailors would find useful. While *The New Practical Navigator* included instructions to sail from England, this edition included how to sail from the United States.

The New American Practical Navigator, published in 1802, included a glossary of nautical terms defined so any sailor could understand them. Chapters included discussions of piloting and sailing techniques, logarithmic tables needed for navigation, geographical terms, and how to adjust a sextant, use a compass, and calculate latitude. There was a chapter with directions for how to sail from the United States to India. It was and is considered a practical, functional encyclopedia of navigation. It is still used today.

For his innovative work on navigation, Bowditch received honorary degrees from Harvard University: master of arts and doctor of laws. The U.S. government bought the copyright to *The New American Practical Navigator* in 1866 and changed its title to *The American Practical Navigator* in 1880. Over 50 editions have been published since, with updated and revised information as technology has improved navigation techniques. The pdf (portable document format) file of the book is available online for free.

Linda Briley-Webb

See also Vol. 1, Sec. 3: Equatorial Sextant; Solar Compass

Further Reading

- Bowditch, Nathaniel. 1861. *The New American Practical Navigator*. New York: E. & G. W. Blunt.

Bowditch, Nathaniel. (original author). 2002. *The American Practical Navigator*. Bethesda, MD: The National Imagery and Mapping Agency, U.S. Government.

Thornton, Tamara Platkins. 2016. *Nathaniel Bowditch and the Power of Numbers How a Nineteenth-Century Man of Business, Science, and the Sea Changed American Life*. Chapel Hill: University of North Carolina Press.

Report on Manufactures (1791)

The *Report on Manufactures* (also called *A Treatise on Manufacturing*) is considered the magnum opus of Alexander Hamilton, the first secretary of the Treasury. It was presented to Congress on December 5, 1791, and is considered the guiding document for the economic principles of the United States. The *Report on Manufactures* was followed by specific reports on banking and credit. The Report was analogous to an economic Declaration of Independence, to be followed by constitutional specifics. It was originally opposed by the then secretary of state, Thomas Jefferson. The disagreement between Hamilton and Jefferson derived from two different visions. Jefferson saw the United States as an agrarian nation where manufacture would be done on large plantations. Hamilton foresaw an urban nation of manufacturing cities. By Jefferson's death in 1825, he had come to accept Hamilton's vision of an industrial America.

The Report was considered a blend of mercantilism as practiced in England and the practices of Jean-Baptiste Colbert of France. It would reject the recent ideas of Adam Smith's free trade and minimal government interference. It would be the foundation of the emerging Federalist Party. Ultimately, Hamilton's ideas would be incorporated in the "American System" of Henry Clay's Whig Party in the 1830s. The young Whig, Abraham Lincoln, would incorporate it into the newly formed Republican Party. Later, in the 1880s, William McKinley would make it the cornerstone of Republican Party platforms for decades to come. Much of Hamilton's vision for the United States has come to pass. In 1790, Hamilton faced a financial mess. The country lacked international and domestic

credit. The currency was worthless, and soldiers paid in script were near rebellion. While free, the country was facing financial collapse.

Hamilton believed that the United States would fail if it did not excel in manufacturing. He reasoned this from his experience as a young military officer under George Washington in the Revolutionary War. The army had suffered from lack of arms, gunpowder, uniforms, iron implements, and ammunition, which nearly cost the States the war. American manufacturing had lacked capacity, and the success of the British blockade had nearly crushed the struggling Continental Army. In the report, Hamilton noted, "The extreme embarrassment of the United States during the late war, from incapacity of supplying themselves, are still matter of keen recollection." After that experience, Hamilton believed that the United States needed to build a strong manufacturing sector if it wanted to remain free. Furthermore, the country lacked a transportation system to supply the army. Hamilton stated, "Those hands, which may be deprived of business by the cessation of commerce, may be occupied in various kinds of manufactures and other internal improvements. If . . . manufactures should . . . take root among us, they will pave the way, still more, to the future grandeur and the glory of America." Hamilton argued that national industries should be supported through protective tariffs, direct subsidies, a national banking system, and a national transportation system. Hamilton refuted Adam Smith's work on the grounds that it was based on an agricultural society.

Hamilton argued for protective tariffs not only to protect infant industries but also to provide a source of revenue for the government. A Congress in need of money to pay off war debts quickly adopted this part of the report. Most opponents were Southerners, such as Jefferson and James Madison, of the Democratic-Republican Party of the time. The South feared that tariffs on imports would cause retaliation affecting their exports of cotton and tobacco. The division would remain and would be the root cause of the Civil War. The Hamilton tariff was to be a moderate one that was of more use in raising money for the government than full protection would have been. The more hotly debated part of Hamilton's plan was direct government subsidies to manufacturers. Most argued for

indirect subsidies such as the building of roads and canals. Even manufacturers preferred a high tariff for protection versus government subsidies, which might lead to political favoritism.

Hamilton was correct in that American industry was starved of cash needed for investment. Banks were almost nonexistent in America except for those serving large planters. England had been the source of capital for America, so banks had failed to fully develop. On Hamilton's recommendation, Congress chartered the First Bank of the United States on February 25, 1791. Hamilton modeled the bank after the Bank of England. The First Bank of the United States was opposed by the Southern states.

Hamilton used the "commerce clause" of the Constitution to justify this expansion of the federal government. The First Bank was a chartered private company with government backing. Stock of \$10 million was sold, with the federal government buying \$2 million of it, which was financed by an excise tax on domestically distilled whiskey. This would ultimately lead to the Whiskey Rebellion. The First Bank did establish order in the newly formed United States. Part of the "bank bill" established a National Mint to replace the more than 30 currencies in circulation. The First Bank allowed New England merchants to establish international credit to promote trade. Furthermore, the First Bank supplied badly needed capital to manufacturers in Pennsylvania, Connecticut, and New York. The bank also served a secondary role as a depository for government accounts. The debate over the bank would lead to the formation of two political parties—the pro-Federalists of Hamilton and the Democratic-Republicans of Jefferson.

The First Bank of the United States was chartered only until 1811, and it continued to be opposed by the Southern states, which saw no benefit from it. The bank's charter was allowed to expire under President Madison, and Congress, by a narrow margin, did not recharter it. Overall, Hamilton's Federalist approach to business would be called "supply-side economics" today. The Federal Reserve today functions similarly to Hamilton's original thinking. Hamilton would have agreed with many government actions to foster manufacturing. Hamilton, however, would not agree with the free trade practices of today.

Quentin R. Skrabec

See also Erie Canal; Jefferson, Thomas; National Road

Further Reading

Chernow, Ron. 2004. *Alexander Hamilton*. New York: Penguin.

Land, Michael. 2004. *Hamilton's Republic: Readings in the American Democratic Nationalist Tradition*. New York: Free Press.

Skrabec, Quentin. 2008. *Pig Iron Aristocracy*. Westminster, MD: Heritage Books.

River Steamer

For all his many accomplishments, Robert Fulton is best known for the development of the commercial steamboat or river steamer. Drawing upon the work of inventor John Fitch, Fulton took Fitch's unwieldy model and turned it into the commercially viable vessel that transformed American travel and trade.

Robert Fulton had lifelong interest in boats and waterways. The early part of his life was spent pursuing a career as an artist, but he abandoned that career to go to Europe to study canal building and invent different types of boats. In 1806, Fulton returned to the United States and devoted himself to the development of a river steamer.

Looking to build upon the ideas of John Fitch, Fulton formed a partnership with prominent New York Founding Father and former ambassador to France Robert Livingston. Aware of a steamboat called the *Experiment* that had made trips on the Delaware River in the early 1790s, Fulton and Livingston sought to take advantage of the Hudson River and the commercial opportunities tied to fast-growing New York City by developing a better steamboat.

Their ultimate production, the *Clermont*, had roots back in experiments relating to the water resistance capacity of various hulls that Fulton began in 1801. Indeed, while in Europe, Fulton was exposed to some of the work being done by the many Europeans who were pursuing similar goals. Putting that knowledge to work, in August 1803, Fulton launched a boat that traveled against the current on the Seine for about a mile and then, turning around, moved with the current

at an even faster speed. While the speed fell well short of the 16 miles per hour that Fulton had envisioned, the trial confirmed Fulton's fundamental ideas about the basic design principles. So pleased was Fulton that he sought to use the demonstration to get support and funding from Napoleon and the French government. But after he was rebuffed, the project lay dormant as the sometimes scattered Fulton turned his attention back to his submarine. When that effort proved unsuccessful, he decided to return to the United States determined to develop a commercially successful steamboat on America waters.

Arriving back in the United States in December of 1806, Fulton focused his attention on building a steamboat that could cruise the Hudson River. He was under some time pressure, as his partner, former ambassador Robert Livingston, had secured a monopoly for steamboat use on the Hudson, but to maintain the monopoly, he had to have a boat in operation by the end of April; otherwise, the monopoly would be lost. Too, an extended delay would mean that the potentially lucrative summer-and-fall travel season would be lost. As April approached, Livingston secured a two-year extension, but in fact, after a few tests in late July, Fulton had a boat ready to be launched on the Hudson River.

Indeed, able to draw upon his European efforts while also being able to adapt some of the existing examples of steam-powered riverboats, Fulton developed a model that became the first economically feasible commercial steamboat. This craft was a side-wheeler paddleboat that had auxiliary sails. The flat-bottomed boat had a square stern and drew only two feet of water. Powered by a coal-fired steam engine brought over from England, the vessel was 146 feet long and 12 feet wide. Not only did it exceed previous efforts in terms of speed and maneuverability, the new boat offered passenger comforts never previously imagined, including sleeping accommodation for lengthy trips.

The boat was originally named the *North River Steamboat*, but in honor of the Livingston family estate on the Hudson, Clermont, the name was changed. The rechristened vessel was launched on August 17, making its first trip up the Hudson River from New York City to Albany. The *Clermont* was an immediate success, and with travelers clamoring, Fulton and Livingston established the North River Steamboat Company,

beginning regular operations between the state's financial center and its capital. While in some quarters Fulton's early efforts were greeted with skepticism, with the boat referred to as "Fulton's folly," not only did it prove to be a commercial bonanza, but within five years, Fulton had boats on six major rivers and the Chesapeake Bay.

In their success in New York, Fulton and Livingston secured exclusive rights to run their steamboats on New York rivers as well as on the lower end of the Mississippi. Fulton recognized that the real need for a service like his was not on the eastern rivers but rather on the western feeders and tributaries, where there were few or no roads. With that in mind, the Company introduced the *New Orleans*. Built in Pittsburgh and launched in 1811 on the Ohio River, the steamer proceeded along until it scraped bottom as it reached Louisville. The incident was a harbinger of problems that the boat would encounter on the western rivers, where sandbars and other natural hazards were commonplace. In addition, while it eventually reached New Orleans, the return trip ended when the *New Orleans* could not buck the current above Natchez. With its creators unable to solve the problem, for its remaining two years on the water, the *New Orleans* simply provided service between Natchez and New Orleans. In the face of these challenges, Fulton and Livingston decided to abandon the western market, refocusing their efforts on the east.

The abandonment of the western routes did not hurt the Company's business. In fact, the number of eastern boats in operation only enhanced Fulton's reputation as an inventor and a businessman. Neither he nor Livingston were able to enjoy their success for long. Livingston died in 1813 after suffering a fatal stroke, while Fulton died in 1815 at the age of 49, succumbing to pneumonia after venturing into the freezing Hudson to rescue a friend.

William H. Pruden III

See also Canals; Flatboat; Fulton, Robert; Steam Engine; Submarine

Further Reading

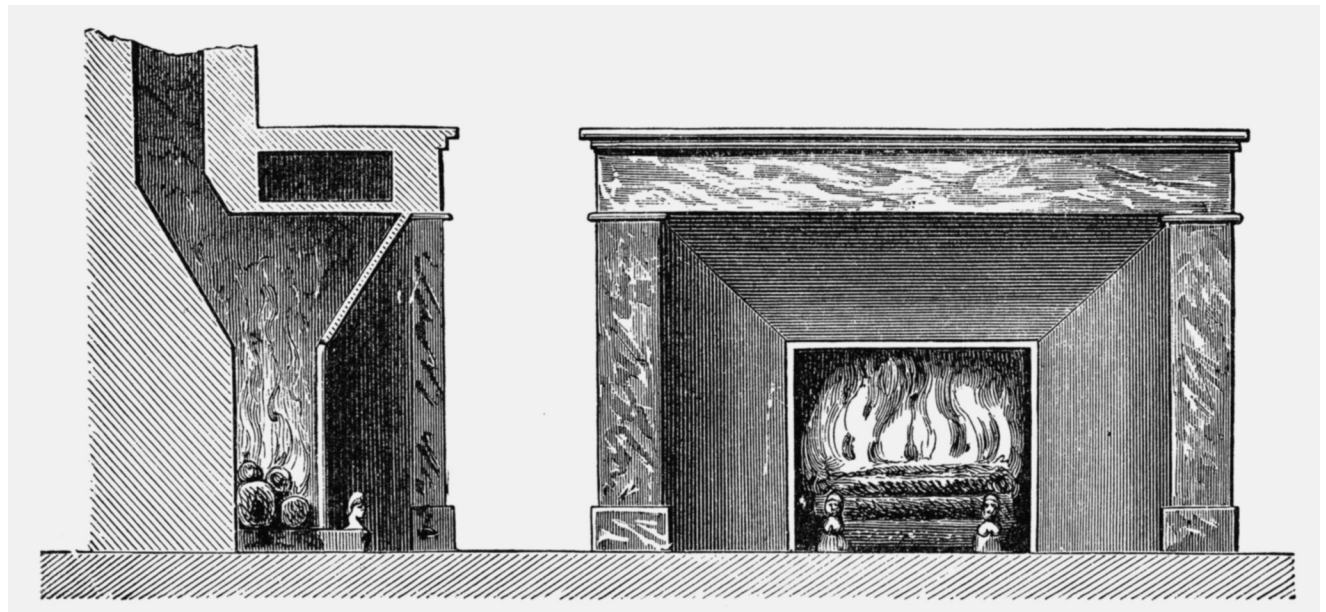
Sale, Kirkpatrick. 2001. *The Fire of His Genius: Robert Fulton and the American Dream*. New York: Free Press.

Rumford Fireplace

American-born Benjamin Thompson invented the Rumford fireplace during the American Revolution. Because he joined the British Army and was later knighted by King George III, the inventor of the Rumford fireplace was also known as Count Rumford. Rumford invented the Rumford fireplace—which became the first modern kitchen range—to improve the quality of London’s polluted air and for the general public to save fuel. He designed the tall, elegant stove as a narrow, shallow construction with a streamlined, rounded, wide-angle throat. This latter area was the space under the damper and above the firebox and was where the fireplace smoke passed through first. Rumford’s curved, repositioned chimney throat funneled the smoke upward and out. With its fluid dynamics, he created a clean-burning fireplace that wasted less heated air by reflecting radiant heat, the most useful heat, away from the fireplace and into the room. It’s a simple fact: a tall fire burns cleaner. Because the Rumford fireplace was tall, it kept the smoke and combustion of flame products hot longer and produced only a small amount of smoke and pollution.

The Rumford fireplace, with its clean, whitewashed plaster firebox, was energy efficient, improved air quality, and became the globally renowned state-of-the-art fireplace by the 1790s. U.S. president Thomas Jefferson had eight of the fireplaces installed in Monticello, his palatial home located in Virginia. Rumford had revolutionized the construction of fireplaces and chimneys and his products were so common, the general public referred to fireplaces as Rumfords. Rumford wrote an essays in 1796 entitled, “Chimney Fireplaces, with Proposals for Improving them to Save Fuel; to Render Dwelling-houses more Comfortable and Salubrious, and Effectually to prevent Chimneys from Smoking,” and in 1798, he wrote another essay to detail his energy-efficient fireplace. Rumford fireplaces swept the country. Chimneys came inside or were incorporated into the exterior walls of houses because it was easier to build them over the shallow fireplaces rather than to slope flues through the wall to an exterior chimney.

The Rumford fireplace was part of the Chicago World’s Columbian Fair exhibit in 1893. It was part of the Massachusetts contribution and the Department of Sanitation and Hygiene’s exhibit officially known as the “Rumford Kitchen.” Besides the Rumford fireplace,



Designed by Benjamin Thompson, Count Rumford, the tall and shallow Rumford fireplace improved fuel efficiency both by its shape and by its use of polished plates, which reflected heat from the firebox into the room. (12/ UIG via Getty Images)

Count Rumford's designs for a baking oven, a double boiler, a pressure cooker, and drip coffee maker were also featured. The Rumford fireplace is even being used to replace decorative fireplaces today, as it remains a fuel-saving, heat-efficient, ecologically correct heat producer in homes throughout the world.

Amy Helene Forss

See also Thompson, Benjamin (Count Rumford); *Vol. 1, Sec. 1: Franklin Stove*

Further Reading

Brown, Sanborn C. 1979. *Benjamin Thompson, Count Rumford*. Cambridge, MA: MIT Press.

Kaldenbach, Robert. 1998. "Lord of the Flues." *Yankee Magazine* (January): 61–64.

Rush, Benjamin (1746–1813)

Benjamin Rush was a physician, educator, and politician who was also a Founding Father of the United States and a signer of the Declaration of Independence. Writing extensively on the topics of medicine, politics, and social issues for nearly 50 years, Rush was the first American physician to become widely known around the world. He elevated the study of medicine in the United States, and his position as an educator gave him far-reaching influence in the profession. Of particular note are his texts on psychiatry, extensive accounts of the yellow fever epidemics of 1762 and 1793, and his descriptions of cholera infantum and dengue fever.

A firm believer in higher education, he was a founder of Dickinson College in Carlisle, Pennsylvania, and Franklin College (now Franklin and Marshall) in Lancaster. Rush was also one of the first to promote the study of veterinary medicine in North America.

He was born on January 4, 1746, in Byberry Township, Pennsylvania. After his father died in 1751, his mother moved to Philadelphia, where she ran a grocery store. At the age of eight, Rush was sent to live with his uncle, who ensured that Rush received an education. He entered the College of New Jersey (now Princeton University) in 1759, earning a bachelor of arts degree the following year at the age of 14.

Rush returned to Philadelphia, and at his uncle's urging, he apprenticed under John Redman, one of the first physicians at Pennsylvania Hospital and the first president of the Philadelphia College of Physicians. Redman encouraged his protégé to study abroad, so in 1766, Rush left North America to attend the University of Edinburgh, which had one of the preeminent schools of medicine at the time.

After receiving his medical degree in 1768, Rush spent several months training at St. Thomas's Hospital in London. While there, he met Benjamin Franklin, who persuaded him to visit France and partially funded the trip. This enabled him to meet other esteemed physicians and scientists of the day.

In 1769, Rush returned from Europe and started his own medical practice. That same year, he was appointed professor of chemistry in the University of Pennsylvania's medical department. The following year, he published *A Syllabus of a Course of Lectures on Chemistry*, the first American text on the teaching of that subject.

An enthusiastic supporter of the American independence movement, he was elected to the Pennsylvania delegation of the Second Continental Congress in July 1776 and signed the Declaration of Independence on August 2. He married Julia Stockton the same year, and together, they had 13 children. Their son Richard Rush, born in 1797, would serve as a cabinet officer or ambassador under four presidents.

In 1777, Rush was commissioned surgeon general of the Middle Department of the Continental Army, but he became so frustrated with the disorganization and corruption he found in the army's hospitals and his superiors' lack of action to correct it that he resigned after only 10 months.

The causes of disease were not yet known in Rush's time, but the many recommendations that he made to improve care in army hospitals were consistent with hygienic practices today, showing movement toward connecting a lack of sanitation and the spread of disease. In his letters to his superiors, he expressed his despair that more soldiers were dying of sickness in the hospitals than were being killed on the battlefield. He recommended that mildly ill soldiers be kept separate from those with more serious illness, that blankets covering dying soldiers not be reused, and

that overcrowding be eliminated. He suggested bathing, washing hands at least once a day, and using clean cooking utensils and clean clothes.

After resigning his surgeon general post, Rush returned to Philadelphia and resumed his private practice. In 1784, he accepted a position as a surgeon at the Pennsylvania Hospital. In 1786, he founded the Philadelphia Dispensary to provide medical care for the poor, the first such institution in the United States.

It was at the Pennsylvania Hospital that one of his greatest contributions to medical science took place, in the form of the reforms he instituted in the care of the mentally ill. Pennsylvania Hospital had been founded in 1751 to care for mental patients and the poor. While the stated purpose of the hospital was to provide treatment and possibly a cure for mental illness, the harsh conditions there were unlikely to help meet that goal.

Patients were kept in filthy, unheated cells and were frequently chained by their waists or ankles to the wall, their heads shaved. The cells were on the ground floor of the building, where crowds would gather to watch the patients' often odd behavior. A fence was built in front of the windows to curb this activity, but it proved insufficient to keep the crowds away. It was also very easy to commit a patient to the hospital. Relatives, friends, or neighbors could simply sign paperwork to apply for someone's admission. The patient could not appeal the decision.

Rush studied this situation for several years, and in 1789, he addressed the hospital's board of managers, requesting improvements in the patients' quarters. He recommended that the open chamber pots be replaced with closed ones to reduce odors. Cells should be furnished with mattresses and chairs, and patients should be allowed reading material. He also suggested that those who were able to work be allowed to do so.

Rush's opinions were greatly respected, and the board immediately resolved to change existing conditions. He later suggested further reforms surrounding the training and employment of suitable people to care for patients. As basic as these reforms seem today, they were entirely new ideas in the treatment of mental diseases in the United States at the time and paved the way for its mentally ill toward a future of possible improvement and even cure.

Rush's interest in mental diseases is also found in his writings and lectures. To him, the study of the mind was an integral part of the field of medicine, and he recommended its adoption into the medical curriculum. In 1812, he published *Medical Inquiries and Observations upon the Diseases of the Mind*, the first textbook on psychiatry in America. This book and an earlier article titled "Influence of Physical Causes upon the Moral Faculties" were for many decades the only American publications on the subject of mental disease. Of major importance was Rush's belief in the curability of mental disease, which he impressed repeatedly upon both the readers of his texts and his students in lectures.

Despite this forward thinking, however, Rush was still a physician of his time and applied treatments that ranged from ineffective to actively dangerous for his patients. He was an enthusiastic proponent of what was known as "depletion therapy." This involved bloodletting and dosing patients with strong purgative medicines that brought on explosive diarrhea. Rush sometimes drained his patients of 6 to 8 pints of blood over several days (the human body contains about 12 pints). He believed in unitary theory—that all disease came from a single source in the body—and that this source was an overstimulated nervous system that caused, in his words, an "irregular convulsive action of the blood vessels." Depletion theory was meant to bring the body back into balance.

Rush would eventually patent his own purgative, "Dr. Rush's Pills," commonly referred to as "thunder clappers." These contained a mercury compound called calomel, and jalap, the tuberous root of a tropical climbing plant.

In 1793, a severe yellow fever epidemic struck Philadelphia. From August until November of that year, 4,000 to 5,000 residents—approximately 10 percent of the population—died of the illness. Rush used his favorite treatments of bloodletting and purgatives in an attempt at a cure but had few successes. About half of his patients died.

Afterward, a number of his colleagues accused him of excessively applying his therapy. Additionally, his insistence that yellow fever arose from unsanitary conditions upset many of his fellow Philadelphians. Despite this, stories of Rush's devotion to his patients

while other physicians (and many other citizens as well) fled the city made him a hero to many.

In the spring of 1813, Rush fell ill with a fever (most likely typhus) and died five days later. He was eulogized by fellow Founding Fathers Thomas Jefferson and John Adams, among others. In 1837, a group of Rush's former students founded Chicago's Rush Medical College in his honor. In 1965, the American Psychiatric Association placed a bronze plaque at his grave in Philadelphia, designating him the "Father of American Psychiatry."

Nancy Beach

See also Vol. 1, Sec. 1: Franklin; Benjamin; Vol. 1, Sec. 3: Nightingale Plan

Further Reading

National Park Service. "Benjamin Rush and the State of Medicine in 1803." <https://www.nps.gov/jeff/learn/historyculture/medrush.htm>, accessed August 23, 2018.

Princeton University. "Rush, Benjamin." https://etcweb.princeton.edu/CampusWWW/Companion/rush_benjamin.html, accessed August 23, 2018.

University of Pennsylvania Archives. "Benjamin Rush (1746–1813)." http://www.archives.upenn.edu/people/1700s/rush_benj.html, accessed August 23, 2018.

Veith, I. 1976. "Benjamin Rush and the Beginnings of American Medicine." *The Western Journal of Medicine* 125: 17–27.

Primary Document: Excerpt from the Medical Writings of Benjamin Rush (1805)

Benjamin Rush was not only an important Founding Father but a man who wrote and thought deeply about the medical sciences. He is considered the "Father of American Psychiatry," having published the first American textbook on the subject—Medical Inquiries and Observations upon the Diseases of the Mind (1812). In his writings, he broke new ground when he wrote about the effects that the mind can have on the body.

V. The exercises of the faculties of the mind have a wonderful influence in increasing the quantity of human life. They all act by reflection only, after having been previously excited into action by impressions made upon the body. This view, of the reaction of the mind upon the body, accords with the simplicity of other operations in the animal economy. It is thus the brain repays the heart for the blood it conveys to it, by reacting upon its muscular fibres. The influence of the different faculties of the mind is felt in the pulse, in the stomach, and in the liver, and is seen in the face, and other external parts of the body. Those which act most unequivocally in promoting life, are the understanding, the imagination, and the passions. Thinking belongs to the understanding, and is attended with an obvious influence upon the degree and duration of life. Intense study has often rendered the body insensible to the debilitating

effects of cold, and hunger. Men of great and active understandings, who blend with their studies, temperance and exercise, are generally long lived. In support of this assertion, a hundred names might be added to those of Newton and Franklin. Its truth will be more fully established by attending to the state of human life in persons of an opposite intellectual character. The Cretins, a race of idiots in Valais in Switzerland, travellers tell us, are all short lived. Common language justifies the opinion of the stimulus of the understanding upon the brain, hence it is common to say of dull men, that they have scarcely ideas enough to keep themselves awake. The imagination acts with great force upon the body, whether its numerous associations produce pleasure or pain. But the passions pour a constant stream upon the wheels of life. They have been subdivided into emotions and passions properly so called. The former have for their objects present, the latter, future good and evil. All the objects of the passions are accompanied with desire or aversion. To the former belong chiefly, hope, love, ambition, and avarice; to the latter fear, hatred, malice, envy and the like. Joy, anger, and terror, belong to the class of emotions. The passions and emotions have been further divided into stimulating and sedative. Our business at present is to consider their first effect only upon the body. In the original constitution of human nature, we were

made to be stimulated by such passions and emotions only as have moral good for their objects. Man was designed to be always under the influence of hope, love, and joy. By the loss of his innocence, he has subjected himself to the dominion of passions and emotions of a malignant nature; but they possess, in common with such as are good, a stimulus which renders them subservient to the purpose of promoting animal life. It is true, they are like the stimulus of a dislocated bone in their operation upon the body, compared with the action of antagonist muscles stretched over bones, which gently move in their natural sockets. The effects of the good passions and emotions, in promoting health and longevity, have been taken notice of by many writers. They produce a flame, gentle and pleasant, like oil perfumed with frankincense in the lamp of life. There are instances likewise of persons who have derived strength, and long life from the influence of the evil passions and emotions that have been mentioned. Dr. Darwin relates the history of a man, who used to overcome the fatigue induced by travelling, by thinking of a person whom he hated. The debility induced by disease, is often removed by a sudden change in

the temper. This is so common, that even nurses predict a recovery in persons as soon as they become peevish and ill-natured, after having been patient during the worst stage of their sickness. This peevishness acts as a gentle stimulus upon the system in its languid state, and thus turns the scale in favour of life and health. The famous Benjamin Lay of this state, who lived to be eighty years of age, was of a very irascible temper. Old Elwes was a prodigy of avarice, and every court in Europe furnishes instances of men who have attained to extreme old age, who have lived constantly under the dominion of ambition. In the course of a long inquiry, which I instituted some years ago into the state of the body and mind in old people, I did not find a single person above eighty, who had not possessed an active understanding, or active passions. Those different and opposite faculties of the mind, when in excess, happily supply the place of each other. Where they unite their forces, they extinguish the flame of life, before the oil which feeds it is consumed.

Source: Rush, Benjamin. 1805. *Medical Inquiries and Observations*. Volume 2. Philadelphia: J. Conrad, 389–93.

Screw-Cutting Lathe

American physicist Henry Augustus Rowland invented the first high-precision screw-cutting lathe. Screws have been in existence for many thousands of years; however, making them wasn't always an easy task. When first invented, screws were often whittled out of wood by hand. This could be done with something like a chisel or a knife and was done with as much precision as one could manage. Even when the first metal screw was created, one would use a file to make threads in it. However, as previously noted, this was a slow and challenging task that wasn't exactly consistent. In 1775, Jesse Ramsden, an English mathematician and instrument maker, created what is currently called the first "modern" screw-cutting lathe—modern in the sense that it involved a leadscrew, slide rest, and gear change mechanism. Ramsden's lathe was revolutionary because it could make 10 screws per minute.

Mass-produced screws continued not to be entirely interchangeable until Henry Rowland perfected the process in the 1880s. In the course of his work on diffraction grating, he found he needed extremely precise screws and had to invent a new process for making them.

Rowland's method has been made obsolete by thread rolling. A modern planetary rotary die can make up to 2,000 screws per minute.

Kalan Small

See also Diffraction Grating; Milling Machine; *Vol. 1, Sec. 3: Twist Drill*

Further Reading

Rybczynski, Witold. 2000. *One Good Turn: A Natural History of the Screwdriver and the Screw*. New York: Scribner.

Screws and Screw-Making, with a Chapter on the Milling Machine. n.d. Colchester, UK: Britannia.

Slater, Samuel (1768–1835)

Textile manufacturing was the first major industry in the United States to develop the factory system of production, and Samuel Slater played a significant role in developing the model that many of the earliest American mills followed.

American attempts to move textile manufacturing away from home-based production into a factory setting were hampered by British competition and by the fact that the British closely guarded the technology and expertise used in textile manufacturing. Britain outlawed the exportation of textile-making machinery or plans for such machinery. People known to be experienced in this field were not allowed to emigrate, and there were penalties imposed on foreigners trying to recruit such workers. These regulations, however, were difficult to enforce. Slater was one of the first British-trained textile mill operators to bring his knowledge and experience to the United States.

Slater was born June 7, 1768, in Belper in the region of Derbyshire in England, which was at the center of the developing textile industry. In 1783, he became an apprentice in a spinning mill under Jeremiah Strutt, who was a partner of Richard Arkwright, the inventor who had perfected waterpowered machinery for spinning cotton thread and provided one of the first major steps toward factory production of textiles. Strutt was one of the first industrialists to become wealthy from investments in that industry. Slater served a six-year apprenticeship under Strutt and eventually became a supervisor of machinery and mill construction.

Slater's apprenticeship ended when he was 21 years old, and he decided that there would be greater demand for his skills and expertise in America than in Great Britain. Despite the laws designed to keep people with such knowledge from emigrating, Slater sailed to the United States under an assumed name, listing his occupation as "farm laborer." He guarded his plans so secretly that he did not even inform his mother until he mailed a letter to her just hours before sailing.

When Slater arrived in November 1789, the U.S. textile industry was still primarily based in home or small shop manufacturing. Cotton thread was spun by one home-based worker, and then the thread was taken

to a weaver, who wove it into cloth. Weavers, however, could use more thread than home-based spinners could produce, so if the thread-making process could be sped up, there would be a ready market for the thread. In the United States, Slater first went to work for the New York Manufacturing Company, which was trying to establish textile mills in that state. Slater found the equipment that this firm was using to be inadequate, and he doubted that it had access to the resources needed for a waterpowered mill.

He soon after learned that Moses Brown, a wealthy businessman in Providence, Rhode Island, was trying to find someone who could repair and operate some spinning machinery that had been constructed in the United States in an attempt to duplicate British designs. Brown had recognized that the home production of thread created a bottleneck because spinners could not keep up with the demands of weavers, and he sought to mechanize the spinning process as British mills had. Slater inspected Brown's machinery and saw improvements that could be made. He convinced Brown to allow him to start from scratch and redesign the machinery needed for a thread-spinning mill.

Working with American carpenters and machinists who had no background with the kind of equipment he was building, Slater created a carding machine and a water frame spinning machine based on Arkwright's prototypes. "Carding" is the process of untangling cotton fibers, cleaning them, and forming them into a "sliver" or wispy cord that can be run through a spinning machine. The "water frame" was a spinning machine capable of spinning multiple bobbins or spindles of thread simultaneously, powered by a water-wheel. It is often said that Slater used his knowledge of British spinning machinery and duplicated their designs, but it is more accurate to say that he created new designs based on his experience with British prototypes. Brown was in partnership with William Almy, another Providence businessman, and Slater agreed to set up the machinery for a share of ownership in the mill.

In 1792, Slater built a waterpowered mill in an existing building in Pawtucket, Rhode Island, which was the first cotton-spinning mill in the United States. The machinery was so simple that nine children, ranging from 7 to 12 years old, were hired to operate it under Slater's supervision. Like most of the early

textile mills in America, this factory produced only cotton thread—which was, again, sold or contracted out to weavers who wove cloth in small shops or home-based businesses. A larger mill in a new building was constructed in 1793, and by 1800, over 100 people worked in this mill.

While Brown and Almy needed Slater's expertise and thus had to agree to include him in a partnership, their relationship was strained, and they tended to view Slater as an employee and also as a potential challenger who needed to be kept in check. All funds for supplies and for paying employees had to come through Brown and Almy's mercantile business in Pawtucket, and they were often late in supplying Slater what he needed to keep the mill running efficiently. Almy and Brown tended to view the mill as simply a part of their larger business activities and not as its own separate enterprise.

Eventually, Slater began building his own mill, although for a time, he maintained his connection with Almy and Brown and oversaw production at their mill. In 1798, he founded Samuel Slater and Company with investments from several people to whom he was related by marriage. He built a mill at Rehoboth, Massachusetts—just across the Pawtucket River from the Rhode Island mill owned by Almy, Brown, and Slater. This mill, sometimes known as the White Mill, was the first in Massachusetts to use Slater's adaptations of Richard Arkwright's waterpowered spinning machines.

Embargoes of British imports during the period leading up to the War of 1812 and the war years of 1812 to 1815 caused demand for American textiles to boom, since there was no competition from British cloth. With many fast-flowing streams to provide waterpower, New England quickly became the center of the new industry. But the end of the War of 1812 brought a time of British "dumping" goods on the American market at low prices. This led many mill operators to begin to incorporate weaving into their mills to undercut this British competition instead of sending their thread to outside weavers. Mills that did both spinning and weaving were often referred to as "integrated mills." The final finishing of cloth by dyeing or bleaching, however, continued to be farmed out to other businesses until late in the 19th century.

In Slater's earliest mills, children did most of the work tending the spinning machines under the oversight of a few adult male supervisors. Men also worked in the mills as mechanics maintaining the machinery and at times building the equipment, since most mills had machine shops for such purposes. Families were recruited to move to the towns surrounding these mills, but at first, Slater sought to keep the fathers in these families involved in traditional work such as farming. He wanted to preserve the traditional family structure, with the father as the chief authority in the home and the one who made the economic decisions for the family. Men might work as laborers on a farm operated by the mill, or they might work individual plots of the company's land on their own as sharecroppers.

Over time, however, opportunities to keep adult males occupied in work outside the mills decreased, and so entire families often came to work in them, especially after power looms were added for weaving fabric. The towns that grew up around Slater's mills tended to maintain the appearance of an idealized New England village of the colonial era; the kinds of large factory buildings and dormitories for workers that characterized Lowell, Massachusetts, and the other mills operated by the "Boston Associates" were slow to appear around Slater's mills. Workers worked long hours for fairly low wages in these mills, but economic historians generally believe that the conditions and pay were fair for the times in comparison to the few options that employees might find elsewhere.

Over his career, Slater played a part in developing many mills in the three-state region of Connecticut, Massachusetts, and Rhode Island. In 1808, there were only 15 power cotton mills in the United States, and Slater owned or was co-owner of eight of these. By 1828, he had been partners in 13 different mill enterprises. Slater trained three of his sons in the milling business, but they did not take significant roles in management until the firm of Samuel Slater and Sons was formed in 1828. They continued the business after their father died.

By the time of Samuel Slater's death on April 21, 1835, the New England textile industry was second in size only to Great Britain's; textile manufacturing was one of the major economic activities in New England and employed thousands of workers. President Andrew

Jackson visited Slater in New England in 1833 and pronounced him “the father of American manufacturers.” Slater’s original mill in Pawtucket is maintained today as a museum and historic site.

Mark S. Joy

See also Cotton Gin

Further Reading

Gordon, John Steele. 2004. *An Empire of Wealth: The Epic History of American Economic Power*. New York: Harper Collins.

Tucker, Barbara M. 1984. *Samuel Slater and the Origins of the American Textile Industry, 1790–1860*. Ithaca, NY: Cornell University Press.

Steam Engine

The steam engine was a central invention of the 19th-century Industrial Revolution. Steam power moved boats, trains, water pumps, and much more. A steam engine uses steam as the working fluid to produce mechanical work. Unlike gasoline engines, steam engines are external combustion engines because the working fluid (the steam) is separate from the combustion (the fire that heats the water to make the steam).

Samuel Morey was an early pioneer of internal combustion engines, but he first worked on steam engines, inventing a steam-powered boat in the 1790s. During his stint as an inventor, he was granted over 50 patents for work involving-steam powered boats and engines that used turpentine vapor, among other things.

The earliest recorded steam engine was built by Hero of Alexandria in the 1st century AD. Hero named his machine the “aeolipile” or “Hero’s engine.” Hero’s engine was a steam turbine that consisted of a rotating surface, like a sphere, that was heated with some external source and produced rotation about its axis. Although it was the first recorded steam engine, it saw little to no practical use. One of the first commercially recognized, patented inventions came in 1698 by way of a steam-powered water pump. It was invented by Thomas Savery and was used in coal mining to pump out mines flooded with water.

At their most basic, steam engines are composed of two parts: the boiler, which generates the steam; and the motor unit, which converts the steam into power. While steam engines for boats and locomotives had these two parts in close proximity to each other, stationary steam engines could have the two parts in separate, fixed buildings. Reciprocating steam motors use cylinders, pistons, connecting rods, and flywheels. This type of engine was widely used for most of the 19th century. Some steam engines have condensers to control exhaust while others have pump injectors to move water into the boiler during engine operation. In the 19th century, almost all of these steam technologies were driven by coal, increasing the demand for coal mines and coal miners. Coal boxes often had a chain or screw-stoking system that moved the coal from the coal bin to the engine’s firebox. Some steam engines, notably on early locomotives, required a worker to shove coal manually into the firebox.

In 1712, Englishman Thomas Newcomen invented the first piston-driven steam engine. Scotsman James Watt patented a 10-horsepower steam motor that utilized a partial vacuum. By the early 1800s, steam engines were powering factory machines, pumping stations, railway locomotives, steamboats, and some road vehicles and submersible technology. Steam tractors and steam combines appeared on American farms in the 1840s. Though little remembered, the Stanley Motor Carriage Company manufactured a steam-powered automobile between 1902 and 1924.

American factories were steam powered in the 1800s. Textile factories featured both steam-powered “spinning mules,” which spun cotton into thread or yarn, and power looms, which mechanized the weaving process. While such technological innovations are often celebrated, mechanizing the textile industry first reduced wages and then caused wide-scale unemployment among skilled weavers. Also, the mechanized nature of steam-powered factories meant that skilled workers could be replaced with low-waged, unskilled workers. Nineteenth-century textile workers, many of them young women and children, worked 12-hour days, six days a week in factories that were often unsafe and uncomfortable.

The now-iconic steam railway locomotive was first invented in 1784 by Scotsman William Murdoch.

The first American-built steam locomotive to operate on a public railroad was the *Tom Thumb* locomotive. In 1830, inventor and philanthropist Peter Cooper designed and built the small steam engine. The *Tom Thumb* came to public notice when it was featured in a race against a horse. At first, the engine made a good showing in the race, easily pulling away from its equine competition, but the engine threw a pulley belt, lost power, and lost the race. Nonetheless, *Tom Thumb*'s performance made people understand that steam locomotives were the coming thing. By mid-century, steam locomotives ruled the American transportation revolution. They also became crucial in the prosecution of the Civil War. The Union simply had more miles of railroad, more steam locomotives, and better facilities for making new engines and repairing old ones than did the Confederacy.

Steam turbines also played a significant role in the Industrial Revolution. Steam engines were designed to be used as turbines (rotary-powered, energy-producing machines) in the late 19th century. Steam turbines proved so successful that they gradually replaced piston-driven systems. Steam turbines still produce almost 90 percent of the electrical power in the United States and were widely used to propel large ships for most of the 20th century. Modern steam turbines are powered with solar energy, geothermal energy, internal combustion engines, or hydroelectric energy. While coal is also still used to power electrical plants, this type of energy production fell out of favor by the end of the 20th century because it is a “dirty” and unsustainable energy production system.

While steam engines powered the 19th-century Industrial Revolution with its attendant positive and negative realities, the gasoline-powered, internal combustion engine largely replaced steam by the end of the century. Some countries, like Malaysia, still use steam engines to run locomotives. In Sweden, the company Energiprojekt AB is working on a modern five-cylinder steam engine that uses superheated steam. The company hopes to create a clean engine that can replace gasoline-powered, internal combustion engines.

Bryan Cabrera

See also Fulton, Robert; High-Pressure Steam Engine; Internal Combustion Engine; Morey, Samuel; Steam

Tractor; Steamboat; *Vol. 1, Sec. 3: Best Friend Steam Engine*; Railroads; *Vol. 2, Sec. 1: Electricity, War of the Currents*; *Tom Thumb Locomotive*; *Vol. 2, Sec. 2: Hydroelectric Power*

Further Reading

Hills, Richard. 2000. *Power from Steam: A History of the Stationary Steam Engine*. Cambridge: Cambridge University Press.

Rosen, William. 2010. *The Most Powerful Idea in the World: A Story of Steam, Industry and Invention*. New York: Random House.

Steam Tractor

The steam tractor is a piece of machinery that was used in place of a horse-drawn plow to efficiently prep an area of land for use in farming in the late 19th and early 20th centuries.

Originally developed in the early 19th century, the steam tractor was an innovative piece of technology that, during its era, revolutionized the agricultural industry. There were two distinct areas that began to develop this new form of technology: North America and Great Britain. This particular piece of equipment was originally a simple steam engine placed on skids or wheels and transported to a specific work area by a team of horses. Further development of the steam tractor allowed the steam engine to power its own movement using a traction drive, which gave the equipment more independent mobility and allowed it to be moved without the use of horses. These driving mechanisms can be separated into three categories: shaft, chain, and open pinion. They allowed the steam engine to be an extremely viable option for agricultural use around the world.

Steam tractors in the early 19th century were developed for two main purposes: to plow fields and thresh grain. They were extremely expensive at first, so farmers banded together to rent them to complete large jobs quickly. This could not have been possible had they used only horses.

The steam tractor was an important innovation that led to modern farming. Without it, it would have been much more difficult in the last two centuries to grow enough food to support the world's growing

population. The steam tractor was an early form of today's plowing equipment; it was slowly phased out of operation by the 1920s. The much more efficient internal combustion engine replaced the steam engine, emerging just after World War I.

Cody J. Swanson

See also Cotton Gin; Steam Engine; Steamboat

Further Reading

- Arnold, Dave. 1988. *The Iron Workhorse: American Gas Tractors and Steam Traction Engines*. Minneapolis: Motorbooks Intl.
- Erb, David, and Eldon Brumbaugh. 1993. *Full Steam Ahead: J. I. Case Tractors & Equipment, 1842–1955*. St. Joseph, MO: American Society of Agricultural Engineers.
- Spalding, John F., and Robert T. Rhode. 2011. *The Steam Tractor Encyclopedia: Glory Days of the Invention That Changed Farming Forever*. Dayton, OH: Book Factory Press.

Steamboat

A steamboat is a waterborne vessel propelled by steam power that usually drives paddle wheels. Steamboats were the means by which the United States grew from its infancy into a prosperous, expanding nation in the 1800s before the coming of the steam locomotive.

With America's vast system of interconnected rivers and waterways, steamboats linked isolated communities with the larger world, cutting huge distances and travel time to a fraction of what they had been. From the early 1800s to the 1870s, steamboats turned waterways such as the Mississippi and Ohio Rivers into the superhighways of their day, churning the waters up- and downstream like a latter-day rush hour. Mark Twain made riverboat pilots into larger-than-life figures in American culture, just as riverboat gamblers entered their own mythology. Both species flourished in the era of the steamboat.

Steamboats are not to be confused with "steamships" (often called "steamers"). After the invention of river steamboats in the early 1800s, steam power

began to be used for larger, oceangoing vessels. Steamships, though also powered by a steam-generated system utilizing paddle wheels or propellers, are heavier vessels that can travel the major seas and oceans of the world. Steamboats, often called "riverboats," do not require deep water and usually ply rivers and lakes.

Before the heyday of steamboats in America, there were the flatboats. Moving produce to markets and occasionally carrying passengers, flatboats were an important form of transportation in America even before it became a nation. The colonies, still fighting their War of Independence, took note in 1781 when Pennsylvania farmer Jacob Yoder plied the Monongahela River in a flatboat to carry flour. In 1782, Yoder became the first recorded person to successfully navigate a flatboat from Brownsville, Pennsylvania, to New Orleans, Louisiana, demonstrating how waterways could be used to reach distant locales.

Flatboats were rectangular, flat-bottomed, tub-like boats that were relatively easy and inexpensive to make. Though built in various sizes and configurations depending on the load and distance to be traveled, they were often about 4 feet wide and 16 feet long with no covering, or just a simple shelter with a cooking area. They were guided by a flatboatman with a paddle attached to a long pole. With their long, narrow shape and shallow draft, flatboats could navigate America's ample supply of rivers and even creeks. But flatboats had a huge drawback: they could only go one way. They could usually only travel by being carried with the current downstream, literally able only to "go with the flow." When flatboatmen reached their destination, they dismantled their boat, sold it for lumber, and would often walk home.

Still, with the abundance of small waterways in North America, during the first half of the 1800s, flatboats became one of the most important modes of shipping in the United States. Once the flatboats followed the streams of America's heartland to join the Mississippi, the current could propel them to New Orleans, where their products could be shipped overseas. Most often, their cargo included corn, flour, fruit, furs, pork, vegetables, and whiskey. Though flatboats were slow, uncomfortable, and easily attacked by marauders, passengers could be carried alongside cargo, usually having tent-like coverings for shelter.

While flatboats continued to be an important means of transport on smaller waterways as the 1800s progressed, steamboats started to appear on western rivers in 1807, much to the delight of both shippers and passengers, who found them far more efficient, faster, and boasting one important advantage: they could also travel *upstream*.

The steamboat age began soon after Scottish inventor James Watt (1736–1819) patented his version of the steam engine in 1769. John Fitch (1743–1798) was granted a U.S. patent for a steamboat in 1791 after making the first successful trial of his 45-foot steamboat on the Delaware River in 1787. Fitch would go on to build larger vessels that carried passengers and freight to and from Philadelphia, utilizing various combinations of propulsion, including paddle wheels and screw propellers. However, due to construction and operating costs, Fitch was unable to make his venture an economic success.

After the death of John Fitch, American engineer and inventor Robert Fulton (1765–1815) built his first steamboat. It was Fulton who was to become known as the father of steam navigation, after being originally mocked by naysayers as the perpetrator of “Fulton’s folly.”

Fulton had married into New York’s wealthy Livingston family. With their support, he built the first commercial steam riverboat, the *North River Steamboat* (later known as the *Clermont*, named for the Livingston estate in upstate New York). On August 7, 1807, Fulton’s *Clermont* traveled 150 miles up the Hudson River from New York City to the state capital of Albany, steaming into history. By transporting passengers on the *Clermont*’s round trip to great acclaim, Fulton is generally credited with developing the first commercially successful steamboat.

Fulton’s destiny was joined with that of waterborne shipping in the United States. He was appointed a member of the Erie Canal Commission, where he served until his death. He and his partner Robert Livingston worked in 1811 to design the steamboat *New Orleans* to put it into service as a passenger and freight boat along the Mississippi River. To do so, they joined with another partner, also from a distinguished New York family, Nicholas Isaac Roosevelt (1767–1854).

Their plan was to build the *New Orleans* specially designed to make the long trip from Pittsburgh, Pennsylvania, down the Ohio River. The journey would include stops at Wheeling, Virginia, and Cincinnati, Ohio. The boat would have to pass through the Falls of the Ohio at Louisville, Kentucky; continue to Cairo, Illinois; and meet the juncture with the Mississippi River. It would then pass St. Louis, Missouri; Memphis, Tennessee; and Natchez, Mississippi, on its way to the town of New Orleans, Louisiana, on the coast of the Gulf of Mexico. Roosevelt not only introduced his partners to the vertical paddle wheel for steamboats but would also navigate the first voyage on their untried vessel himself, accompanied by his pregnant wife, Lydia Latrobe Roosevelt (1791–1878).

The steamboat *New Orleans* was the first on the western waters. She set out on her journey downriver from Pittsburgh on August 26, 1811. It is important to note that the voyage of the *New Orleans* took place only eight years after the United States had acquired the vast, unknown Louisiana Territory in 1803. The rivers and lands surrounding the Roosevelts were not yet well settled, mapped, or protected.

Not only were those perils daunting enough, but passing Missouri, the Roosevelts would encounter one of the major natural disasters in American history: the 1811–1812 New Madrid Earthquake, which began on December 15, 1811. In a calamity that is expected only every 350 to 400 years, some streams ran backward, the banks of the Ohio and Mississippi Rivers crumbled, islands appeared where there had been none, and others disappeared overnight—one of which was once to serve as a tie-up point for the steamboat. The air filled with sulfur, the sun was blacked out, downed trees and other debris filled the river, and terrified animals flocked to stay near equally terrified humans. But the *New Orleans* was built and balanced well enough that she was able to continue her journey, even though, as Lydia wrote, “I lived in a constant fright, unable to sleep or sew or read.” Finally, as the steamboat neared Natchez, Mississippi, in late December, the earthquake began to abate, and the Roosevelts were greeted by cheering crowds. Continuing her journey, the steamboat reached her namesake city of New Orleans on January 10, 1812.

The crowning achievement of the steamboat *New Orleans* was to reverse course and successfully sail back upstream on the Mississippi against the current. In that one move, she changed the course of transportation in America.

By 1814, Robert Fulton and his partners were offering regular steamboat and freight service between New Orleans and Natchez. Their boats traveled at the rates of eight miles per hour downstream and three miles per hour upstream.

Steamboat design continued to improve. Between 1814 and 1834, annual steamboat arrivals at the port of New Orleans increased from 20 to 1,200.

In the western United States, riverboats transported cargoes of cotton and sugar as well as passengers. In the East, steamboats contributed significantly to the economy by transporting agricultural products and raw materials to fuel the Industrial Revolution.

Larger than canal boats or flatboats, steamboats had a steam engine that turned a paddle wheel, which was usually at the back of the vessel. Some had two paddle wheels, one on each side of the steamboat—which could then reach greater speeds. The paddle wheels propelled the steamboats both up- and downriver and allowed them to travel much faster than the flatboats they had replaced. Steamboats carried more cargo, had room for paying passengers, and did not have to be dismantled after the trip.

Steamboats also had a shallow draft and efficient flat-bottomed construction that allowed them to navigate rivers that were only 10 feet deep. Though many of America's rivers and streams are wide, they are often relatively shallow. Steamboats frequently influenced shoreline patterns; farmers would grow crops along the river because it was easy to get them to market. Small towns and growing cities emerged near rapids and forks in the rivers.

Because steamboats were stable and comfortable to ride on, luxury accommodations were built on some, enticing the wealthy to board riverboats and bringing greater financial resources to America's new frontiers.

Providing previously unseen levels of comfort and speed, steamboats of the 1800s captured the imagination of the American people. Even poorer people could secure passage if they didn't mind sleeping on freight decks, using bales of cotton or sacks of grain for beds.

The finer steamboats offered luxurious onboard accommodations for those who could afford them. Grand salons under gilded ceilings ran the length of some boats, usually about 300 feet. Furnishings were elegant, with their heavy wood reflected by mirror-lined walls. Private cabins on the upper decks were available for the wealthy, along with fine food and drink. While on board, games of chance among passengers were not unknown, giving rise to the era of the riverboat gamblers.

There were also races between rival steamboat captains. Some wished to provide entertainment for their passengers or to secure bragging rights on the river. For others, it was strictly business as they tried to beat other boats to the next landing to pick up goods or paying passengers before anyone else. Since steamboat races often resulted in accidents, boiler explosions, or fires, federal safety legislation in 1838 and 1852 sought to put a stop to them, though some racing continued well after the Civil War.

Ironically, one aspect of the steamboat era is the one image of it most recognizable today, yet it is technically incorrect. "Showboats" brought rousing entertainment to isolated port towns, but they were not steamboats. Showboats were essentially barges that had to be pushed by a small tug, since the stage and auditorium took up space amidships where the steam engine would normally need to be placed.

As the importance of steamboats rose astronomically, the General Survey Act was passed by Congress in 1824 to authorize surveys made of transportation routes "of national importance, in a commercial or military point of view, or necessary for the transportation of public mail." The 1824 Navigation Act appropriated \$75,000 (about \$1,650,000 in 2015 dollars) to improve navigation on the Ohio and Mississippi rivers. The 1826 Rivers and Harbors Act authorized additional surveys and maritime construction projects.

By the 1850s, steamboats dominated river transportation. In the western United States, there had only been 17 steamboats plying the rivers in 1817. By 1855, there were over 700.

Steamboats went to war between 1861 and 1865. Along with the ability to carry more goods and passengers, the increased power of a steam engine allowed the development of armored warships. The *Monitor* and the *Merrimack*, steam-powered ironclad vessels,

saw action during the Civil War when they fought off Hampton Roads, Virginia, in 1862.

The speed and maneuverability of steamboats outclassed older sailing ships by far. Federal steamboats proved vital in securing the Mississippi River and other major waterways, influencing the course of the war and the Union's victory.

In peacetime, along with their luxury and relative safety, there were also dangers to traveling by steamboat that could not be denied. With all-wood boats powered by the blazing fires that generated steam, there were boiler explosions and catastrophic fires. By 1848, steamboat explosions in the United States had cost the lives of almost 2,000 people and untold numbers of animals on board, destroying over 200 boats. Obstacles and snags such as fallen trees in the water caused some riverboats to sink. Sandbars and shifting channels, occurring due to changes in a river's path, made waterways such as the Mississippi virtual obstacle courses. During his American tour of 1842, British author Charles Dickens described the Mississippi as "an enormous ditch, sometimes two or three miles wide, running liquid mud . . . its strong and frothy current choked and obstructed everywhere by huge logs and forest trees."

When snowmelt from northern streams brought high water every spring, shorelines were scoured and eroded, dragging land, buildings, and huge trees into rivers like the Ohio and Mississippi. In especially big floods, the curving lower Mississippi was disastrously prone to cutting across one of its meanders to create a new channel. Steamboat pilots, such as those described by Mark Twain, had to rely on experience, word of mouth, and sometimes just their instincts to guide their way through treacherous, shifting channels. One narrow stretch of the Ohio River was nicknamed "the

Graveyard" because of the number of wrecks that occurred in the snags of its channel when riverboat pilots miscalculated.

The most appalling steamboat catastrophe, which remains the worst maritime disaster in U.S. history, took place on April 27, 1865. In the flood-swollen Mississippi, the steamboat *Sultana* exploded and sank while transporting former Union Army prisoners of war back home just after the Civil War ended. By dark of night, the all-wood boat was quickly engulfed in flames, and passengers who were not scalded or burned to death awoke to find themselves drowning in the rushing currents of the river. At least 1,800 people, including about 40 women, were killed.

Despite the dangers, America's steamboat era flourished until railroads adopted steam technology to power locomotives, with rail travel beginning to overtake it by the 1870s. Just as steamboats supplanted the canal era, railroads replaced steamboats as the major transporter of both goods and passengers. But during their heyday, steamboats plied the nation's rivers as if on a watery superhighway.

Nancy Hendricks

See also Canals; *Vol. 1, Sec. 3: Steam Locomotive*

Further Reading

- Hunter, Louis C. 2012. *Steamboats on the Western Rivers: An Economic and Technological History*. Cambridge, MA: Dover.
- Kotar, S. L., and J. E. Gessler. 2009. *The Steamboat Era: A History of Fulton's Folly on American Rivers, 1807–1860*. Jefferson, NC: McFarland.
- Schneider, Paul. 2013. *Old Man River: The Mississippi River in North American History*. New York: Henry Holt.

Primary Document: Newspaper Announcement of Robert Fulton's Steamboat (1807) and Charles Dickens's Account of His Ride on an American Steamboat (1842)

The following are documents describing steamboats in 19th-century America. The first is a newspaper announcement of the sailing of Robert Fulton's early steamboat on the Hudson River in New York in 1807.

The second is an excerpt from American Notes by British novelist Charles Dickens, who visited the United States in 1842. In this excerpt, Dickens writes about his experience on an American steamboat.

Fulton's Steamboat

"Mr. Fulton's ingenious Steam Boat, invented with a view to the navigation of the Mississippi from New-Orleans upwards, sails to-day from the North River, near the State Prison, to Albany. The velocity [sic] of the Steam Boat is calculated at four miles a hour; it is said that it will make a progress of two against the current of the Mississippi; and if so it will certainly be a very valuable acquisition to the commerce of the Western States."

Source: [New York] *American Citizen*, August 17, 1807.

Dickens's Account from American Notes

Occasionally we stop for a few minutes, maybe to take in wood, maybe for passengers, at some small town or village (I ought to say city, every place is a city here); but the banks are for the most part deep solitudes, overgrown with trees, which, hereabouts,

are already in leaf and very green. For miles, and miles, and miles, these solitudes are unbroken by any sign of human life or trace of human footstep; nor is anything seen to move about them but the blue jay, whose colour is so bright, and yet so delicate, that it looks like a flying flower.

Through such a scene as this the unwieldy machine takes its hoarse sullen way: venting, at every revolution of the paddles, a loud high-pressure blast; enough, one would think, to waken up the host of Indians who lie buried in a great mound yonder. . . . The very river, as though it shared one's feelings of compassion for the extinct tribes who lived so pleasantly here, in their blessed ignorance of white existence, hundreds of years ago, steals out of its way to ripple near this mound: and there are few places where the Ohio sparkles more brightly than in the Big Grave Creek.

Source: Dickens, Charles. 1842. *American Notes for General Circulation*. London: Chapman and Hall.

Submarine

While best known for the development of the commercial steamboat, Robert Fulton was also instrumental in the development of the submarine, which, in an admittedly different form, remains an important component of every major navy in the world.

As a young man during the American Revolution, Fulton worked in a gunsmith shop, where he discovered the power of gunpowder. That interest, coupled with his longtime interest in all things nautical, led him to undertake the development of the torpedo, an underwater weapon similar to a modern water mine. That work, in turn, led to the exploration of an underwater "diving boat," a submarine, that could serve as the transport for the explosive torpedo.

While he was known to claim originality, especially as he sought funding, it is clear that Fulton's idea and plan for the submarine were drawn at least in part from the recognized earlier work of David Bushnell, who had built a hand-cranked version during the American Revolution. While Bushnell's effort, in practical terms, was unsuccessful, it did plant the idea

of such a vessel in people's minds. At the same time, while building upon Bushnell's practical efforts, Fulton's approach to funding and constructing the submarine was distinctive, based in the belief that it could change the face of international warfare and trade. For Fulton, a central part of the rationale for both the torpedo and the submarine was their ability to allow a smaller nation or force to survive—indeed, to compete—against the larger, more expensive warships of the world's leading nations. In fact, his concerns were as much about the ability of smaller nations to engage in free trade—another subject of longtime interest and that Fulton felt was difficult given the nautical advantages of the large nations in naval warfare.

With a basic concept in mind, Fulton sought funding to make it a reality. He made his first foray in December 1797, submitting a proposal to the French Directory in Paris. He framed the idea as a weapon that could be of great value in their ongoing war with Great Britain and proposed a financing plan in which he would receive a payment for the initial construction and then additional amounts based on the number of guns on the boats that were destroyed. He also offered the French government another option: for a flat fee,

he would direct the construction by the government of a fleet of submarines. But the French rejected the idea. While many dismissed it as impractical, even more saw it as unseemly, a brand of sneaky warfare unfit for gentlemen warriors.

Undaunted, Fulton built a model and went directly to Napoleon. At his urging, in the latter part of 1798, a committee appointed by the government's Marine Ministry studied the plan and issued a positive report that urged the government to allow Fulton to proceed. However, the recommendation was met with silence and, although Fulton railed against the government's inaction, nothing happened. Despite his frustration, Fulton could not abandon the idea of a submarine, and in 1800, he built the *Nautilus* with no governmental support. The craft was cigar-shaped, 20 feet long and 5 feet in diameter. It was driven by a hand-cranked propeller when it was underwater but was propelled by a kite-like sail when traveling on the surface. This combination made it the first submersible vessel to have different types of "engines" for surface maneuvers and submerged travel. No less significant was the fact that the *Nautilus* carried flasks of compressed air that made it possible for its two-man crew to stay underwater for five hours. In successful tests conducted in France, the submarine, carrying a two-man crew, descended to a depth of 25 feet.

Fulton offered his first demonstration of the vessel to a French delegation on the Seine in June 1800. It appeared to be well received, and there is some evidence that the government encouraged his further efforts, for Fulton began to undertake tests in preparation for actually attacking the British. He spent the fall of 1800 stalking the British, but for a variety of reasons, including the probable British awareness of his presence, there was no opportunity for engagement. Nonetheless, his efforts impressed the French, and in early February 1801, they entered into a contract with Fulton that covered the operating costs of the *Nautilus* as well as compensation based on the British ships it would destroy. Fulton also was given access to the naval base at Brest as a base of operations. Accepting the contract, Fulton prepared to take on the British Navy.

The next stage of his saga was a disaster. After bringing the *Nautilus* to Brest and undertaking a new

set of tests, Fulton seems to have abandoned the vessel. Concerned about its speed and maneuverability, he turned instead to longboats as the means to deliver torpedoes to British ships waiting in the harbor. But that did not work. In September, Fulton wrote the French and, while admitting his failure, argued that with more time to work on the torpedoes, coupled with some larger French-built submarines, he could wreak havoc by sneaking into English harbors, where he would release torpedoes. By now, the French had had enough, and when Fulton sank the *Nautilus* to prevent anyone from copying it, their government informed him that they had no further interest in his efforts.

Fulton did make one attempt to interest the British in his submarine, but they deemed it impractical as well as too expensive, although after a number of twists and turns, they did make a deal with him for torpedoes, a venture that proved financially lucrative.

In the end, Fulton abandoned his submarine effort, but not before meeting the U.S. ambassador to France, Robert Livingston, with whom he would partner when he returned to the United States in 1806. To Fulton's surprise, his return was greeted with great fanfare after news of the successful submarine launch became public. That adulation provided a successful launch for his next venture—the steamboat.

William H. Pruden III

See also Amphibious Steam Vehicle; Fulton, Robert; Steam Engine; Steamboat; *Vol. 1, Sec. 1: Turtle Submarine*; *Vol. 1, Sec. 3: Torpedo*

Further Reading

Sale, Kirkpatrick. 2001. *The Fire of His Genius: Robert Fulton and the American Dream*. New York: Free Press.

Suspension Bridge

A suspension bridge is a type of bridge where the deck is supported by vertical suspenders and suspension cables. Suspension cables are connected to the towers and anchored at each end of the bridge.

In the earliest phases of this type of bridge, simple suspension bridges were made with ropes, animal



The Golden Gate Bridge is perhaps the most famous suspension bridge in the world. The load-bearing deck is suspended from cables, making this and other suspension bridges more flexible and more tolerant of wind and earthquakes than rigid bridges. (Corel)

skins, or wood. A Tibetan saint and bridge builder Thangtong Gyalpo built 58 suspension bridges around Tibet and Bhutan (later ones were built with iron chains) in the 15th century. One of those bridges survived until 2004.

James Finley, a land-owning judge in Pennsylvania, designed the first modern iron chain suspension bridge. The 70-foot bridge was built at Jacob's Creek in Westmoreland County, Pennsylvania, in 1801. He later received a patent for his work. In the United Kingdom, one of the oldest suspension bridges that is still in use is the Union Bridge (449 feet in total length); it was built with wrought iron in 1820. Saint-Antoine Bridge (two 120-foot spans) in Geneva was the first permanent wire cable bridge, built by Guillaume Henri Dufour in 1823.

A French engineer named Louis Vicat developed the air-spinning process for the wire cables in 1830. John

Roebing, a contemporary German-born American engineer, perfected the process at the place of building—instead of transporting prefabricated cables. He designed and built the first modern suspension bridge over the Monongahela River at Pittsburgh in 1845 using his cable-spinning process. He had completed the design and construction of many other suspension bridges, including the John A. Roebling Suspension Bridge (with a main span of 1,057 feet) over the Ohio River. He was appointed as the chief engineer for the design and construction of the Brooklyn Bridge (with a main span of 1,595.5 feet) in 1867. However, he died from an accident before he could finish his work. His son, Washington Roebling, completed the project by 1883. Another major development of that time was the use of pneumatic caissons for the bridge foundation. Washington Roebling learned the technique from French engineers and applied his knowledge to the Brooklyn Bridge's construction.

Many suspension bridges with much larger spans have been built over the years around the globe. The Akashi Kaikyo bridge (with a main span of 6,532 feet) in Japan has been the world's longest suspension bridge since it was built in 1998. Five out of top 10 longest suspension bridges are currently located in China. The two longest suspension bridges in the United States are the Verrazano-Narrows (with a main span of 4,260 feet) and the Golden Gate (with a main span of 4,200 feet); they are currently ranked 12th and 13th in the world. Many of the newest suspension bridges (with main spans ranging from 1,765 feet to 5,600 feet) are currently being built in China.

The main forces in a suspension bridge are tension in the cables and compression in the towers. The slender towers are designed to carry compression loads and are stabilized by the suspension cables. The load from the bridge deck is transferred by the cables to the towers and then to the tower foundation. The advantages of this type of bridge are that they can be built over spaces where conventional bridges cannot be. For example, it does not require access from below during construction. It is also considered more earthquake proof than other types. Suspension bridges are also more economical, since less building material is required for them compared to other types of bridges.

Early suspension bridges with chain-link cables were susceptible to failure if one of the links broke. Modern bridges use cables made of a bundles of high-strength steel strands that maintain structural integrity even with the failure of a few of the strands. A major drawback of suspension bridges was observed in the Tacoma Narrows Bridge when it swayed wildly in wind (it was nicknamed "Galloping Gertie") and finally collapsed under 40-mile-per-hour winds in 1940. Scientists and engineers studied the failure carefully and rectified the flaw in the future design of suspension bridges by increasing the stiffness of the bridge deck significantly using a trussed deck system, making it aerodynamically stable.

Mousumi Roy

See also Burr Truss Bridge; *Vol. 2, Sec. 1*: Brooklyn Bridge; Roebling, Emily; Steel Arched Bridge; *Vol. 2, Sec. 3*: Golden Gate Bridge

Further Reading

Buonopane, S. G., and D. P. Billington. 1993. "Theory and History of Suspension Bridge Design from 1823 to 1940." *Journal of Structural Engineering* 119, no. 3: 954–77.

McCullough, D. 2012. *The Great Bridge: The Epic Story of the Building of the Brooklyn Bridge*. New York: Simon and Schuster.

Swivel Chair

A swivel or revolving chair is one with a single central leg that allows the seat to rotate 360 degrees clockwise or counterclockwise. Thomas Jefferson is credited for having invented the first one in 1775. He used his unique revolving Windsor chair in Philadelphia while writing the Declaration of Independence in 1776.

Jefferson bought an English-style Windsor chair from either Francis Trumble or Philadelphia cabinet-maker Benjamin Randolph and modified it to incorporate top and bottom parts connected by a central iron spindle, enabling the top half (the seat) to swivel on casters of the type used in rope-hung windows. The chair was made of poplar, mahogany, maple, oak, and hickory. The chair was first used with a Windsor bench and later with a sofa believed to have been made by Thomas Burling.

The comb-back chair, so named because of a resemblance of the crest rail to a hair comb, was unique for its remarkable revolving mechanism, which was specified to an unidentified craftsman by Jefferson. The chair had two seats and rotated on "a central iron spindle and on rollers made of window sash pulleys set in a groove between the two seats." It had volute-carved ears at the ends of the crest rail and knuckle handholds on the arms. It had 11 spindles rather than the usual 9 forming the back. The seat was round rather than the customary *D* shape, with a pommel and a "dished out" seat.

Over the years, the chair was vastly modified in the joinery at Jefferson's Virginia plantation at Monticello. A new base with bamboo-turned legs made either in the joinery or taken from another chair replaced the original baluster-turned legs. The writing paddle was most likely added in 1791 when Jefferson

switched the Windsor couch with the sofa. Jefferson gave the chair to his daughter Martha Jefferson Randolph, who gifted it to J. R. Kane and who, in turn, gifted it to the American Philosophical Society (APS) in Philadelphia on April 20, 1838, citing the chair's history. Jefferson had served as president of the APS between 1797 and 1815.

Jefferson also designed an integrated office-cum-bedroom in his home at Monticello that fit his style of working and anticipated several features that have become fixtures in modern offices. Among the innovations were early "ergonomic" seating (a swivel chair and hassock), task lighting (candles on the arms of the chair), a database (a lazy Susan bookstand that allowed Jefferson to access four books at once), and a personal copying machine (a pantograph on the table in front of the chair).

Modern-day office chairs have swiveling capacity, but they also have wheels, reclining functions, and gas lifts to adjust the height of their seats. Nonetheless, the basic principles of the swivel chair as designed by Jefferson remain the same.

Abhijit Roy

See also Jefferson, Thomas; Wheel Cipher; *Vol. 1, Sec. 1*: Franklin, Benjamin

Further Reading

Fliegelman, Jay. 1993. *Declaring Independence: Jefferson, Natural Language & the Culture of Performance*. Stanford, CA: Stanford University Press.

Kimball, Fiske. 1925. "Thomas Jefferson's Windsor Chairs." *The Pennsylvania Museum Bulletin* 21: 58–60.

Santor, Charles. 1981. "The Re-Creation of Thomas Jefferson's Swivel Windsor." In *Windsor Style in America*, edited by Thomas M. Voss, 199–200. Philadelphia: Running Press.

Thompson, Benjamin (Count Rumford) (1753–1814)

Sir Benjamin Thompson, known later in his life as Count Rumford, was an American-British scientist and inventor. He improved a number of inventions and made significant discoveries in thermodynamics.

Born in Woburn, Massachusetts, in 1753, Benjamin Thompson demonstrated his intelligence early in life. As a teenager, he was apprenticed to a local merchant. He began to conduct scientific experiments but seemed destined to become a local merchant. In 1772, he married a rich widow and moved to her estate in New Hampshire. There, he enlisted in the colonial militia. In 1776, he abandoned his family to join the British Army at Boston. He was put to work at the Colonial Office, where he researched the explosive force of gunpowder. His experiments won him a place in the Royal Society.

After the Revolution and the disbanding of many British military units, Thompson toured Europe in 1783. The elector of Bavaria was impressed with the young scientist and offered him a position. Thompson sought King George III's permission and received it and a knighthood in 1784. In 1785, Thompson moved to Munich to assume his duties.

Thompson energetically pursued a number of reforms. He rounded up Munich's beggars and introduced free schools for poor children. He raised the military's morale and performance. He introduced the potato, dramatically improving Bavaria's nutrition. Obsessed with the economical preparation of food, Thompson conducted many experiments. As a result of these experiments, he inadvertently invented sous-vide cooking. Despising alcohol, he invented an early coffee percolator to encourage Bavarian soldiers to drink coffee instead of beer.

Thompson continued basic research while pursuing these practical ends. He conducted many experiments on the nature of heat. He invented carefully calibrated instruments to measure heat and light. He devised a standard candle to measure them, leading to the modern unit of the candela. He was made a count of the Holy Roman Empire for his services, and he chose the name Count Rumford after the estate where he'd lived with his wife in New Hampshire.

In 1795, Rumford returned to England as the government of Bavaria collapsed during an Austrian invasion. There, he continued to publish; his work on heat would later underpin the discovery of the law of conservation of energy. In 1796, he devised the Rumford fireplace, a simple alteration to existing fireplaces that

created a narrow passage at the mouth of the chimney. This prevented air turbulence and allowed smoke to rapidly leave the fireplace, improving the lives of countless people. Generations had dealt with smoky rooms for centuries. He also invented an improved industrial furnace, making it easier to produce large quantities of quicklime from crushed limestone. The quicklime could be used for many purposes, including the manufacture of construction plaster, concrete, steel, and explosives.

The Society for Bettering the Condition of the Poor approached Rumford for advice, based on his work in Bavaria. Rumford quickly spun a grandiose scheme out of a small workshop, and his early attempts to research the best way of improving the lives of London's poor developed into the Royal Institution, a scientific workshop associated with the Royal Society. Rumford clashed with the Royal Institution's management constantly; he was accustomed to giving orders with the authority of a king behind them. In 1802, angered by his colleagues and flattered by an invitation from Napoleon Bonaparte, Rumford left England for France. In his absence, the Royal Institution developed into a premier applied research facility.

In Paris, Rumford courted and married the widow of the French physicist Antoine Lavoisier, although they separated not long after. As he aged, Rumford's ego and temper worsened. His archconservative views on race and democracy also did little to encourage friendships, and he was soon ostracized from France's scientific community. He continued to conduct research and tinker with inventions but created nothing of great value in France. He died there in 1814.

James L. Erwin

See also Coffee Percolator; Rumford Fireplace; *Vol. 1, Sec. 1: Franklin Stove*

Further Reading

Brown, Sanborn C. 1967. *Men of Physics: Benjamin Thompson—Count Rumford*. Oxford: Pergamon Press.

James, Ioan. 2004. *Remarkable Physicists from Galileo to Yukawa*. Oxford: Cambridge University Press.

Three-Piece Iron Plow

In 1807, a decade after Charles Newbold earned the first American patent for the iron plow, a man named David Peacock received a patent for his new cast-iron plow. While Newbold's plow had been cast in one piece, Peacock's was cast in three separate pieces. Charles Newbold eventually sued Peacock for patent infringement, receiving damages for the ordeal. Peacock's plow was not different enough to have its own patent, but it did put forth a new idea that would shape American technology.

The three-piece iron plow first found use as a replacement for digging sticks in ancient civilizations such as Egypt and Confucian China. It gave farmers an increased ability to break up soil, bury crop residues, and help control weeds. Farmers in these ancient civilizations began using metal-bladed plows and could use oxen and horses to pull them. While plows were made completely out of iron in China, their designs did not make it to Europe until much later.

With the early stages of American industrial growth came a need for increased farming production. The majority of American farmland was in the Midwest, which was covered with black prairie soil. To compensate for the tough terrain, the wood of plows was sheeted in metal. This was an improvement that made plows more durable. Even though it was now a more durable tool, it was very heavy. Newbold fixed this problem through his studies of cast iron. He was able to cast a plow without using a wooden base, making the contraption lighter, and adding the handles and beam afterward. This new plow was stronger and lighter than any plow had been, but it was not indestructible. The cast iron wore down, making it susceptible to easy breaks. Peacock's invention did not change the material that was used, but it changed the configuration, splitting the plow into three distinct pieces. If Newbold's plow broke down, an entire new plow had to be cast, but if Peacock's plow broke down, the piece that was affected could be replaced.

None of these creations made a fortune for their owners until steel was first used by John Deere in 1833, but that does not diminish their importance. The

three-piece plow gave way to the creation of increasingly complex machines, with the idea that if something broke, the part could be replaced instead of the entire machine. This principle is still used to this day in all forms of technology. David Peacock did not necessarily discover the idea of separation of parts, but he did use the idea in a very practical and functional way.

Damian Rodgers

See also *Vol. 1, Sec. 1: Daylight Saving Time; Vol. 1, Sec. 3: Deere, John and Deere and Company; Polished Steel Plow*

Further Reading

Danbom, David B. 2006. *Born in the Country: A History of Rural America*. 2nd ed. Baltimore: Johns Hopkins University Press.

Meyer, David R. 2003. *The Roots of American Industrialization*. Baltimore: Johns Hopkins University Press.

Primary Document: Petition to Congress Asking for a Renewal of the Patent on Jethro Wood's Cast-Iron Plow (1846)

In 1846, Jethro Wood's heirs presented to the 29th Congress a petition proving the worth of the cast-iron plow and asking for a renewal of the patent for the invention. The excerpt here describes the process whereby Wood came to invent that plow.

Humbly Sheweth:

That jethro wood, deceased, husband of said executrix, and father of said executor, was a man of limited education but of philosophic mind and very benevolent disposition.

About the year of 1813, being a farmer, in was induced to believe that agriculture was very much hindered by the defects in the chief instrument of tillage, the plough. From that period he dovoted himself for six years to the improvement of that important instrument. The plough then in use in Europe and in Amerca was constructed chiefly of unwieldy timbers, in a form which presented great resistance to progress and tof coure requiring very great power. These ploughs had always a heave wrought iron share, made at great expense and requiring frequent and expensive repairs.

Jethro Wood instituted, at great expense, a series of experiments with ploughs of various frms and properties, as to length, height, width and curvature of the mould board, and thickness of the plow share. He constructed many ploughs with his own hands and tested their forms and usefullness in various regions of the country, presenting varieties of soils.

He set for himself three objects:

First. to discover a form of the plough which would perform the work desired in the easiest and best manner.

Secondly. To produce a diminution of the cost of contruction.

Thirdly. Durablility of the instrument.

He had discovered that the mold board of every plough then known presented a surface unequally worn or polished by use.

Before Jethro Wood's invention cast iron ploughshares were unknown. Ever farmer remembers the expense and trouble of carrying the wrought iron ploughshare to the blacksmith every two or three weeks to procure the same to be sharpened and relaid. Mr. Wood suggested to a community, who were so incredulous that it required four or five years of constant demonstration to satisfy them, the use of light cast iron share or cutting edge, nicely adjusted, fastened to the mould board, which was extended for that purpose. The experiment, as it was known, was ultimately successful; and now, it is doubted whether a wrought iron ploughshare can be found in use in the world.

Source: *Public Documents Printed by Order of the Senate of the United States, First Session of the Twenty-Ninth Congress. Vol. 4.* Washington: Ritchie & Heiss, 1846, 51.1–51.2.

Vapor-Compression Refrigerator

In 1805, American inventor Oliver Evans first described a closed vapor-compression refrigeration cycle to produce ice by ether under vacuum. He described it as heat that would be removed from the environment by recycling vaporized refrigerant where it would compress and condense so it could repeat the process over again. Vapor compression is the most commonly used method of cooling.

However, Evans was not the person who created the refrigerator. In 1834, an American expatriate to Great Britain, Jacob Perkins, built the first working vapor-compression refrigeration system in the world. His prototype system worked, although it failed commercially. The first practical vapor-compression refrigeration system was built by James Harrison, who was a British journalist who emigrated to Australia. His patent in 1856 was for a vapor-compression refrigeration system using ether, alcohol, or ammonia.

The vapor-compression refrigeration cycle is approximately a Rankine cycle run in reverse. A working fluid is pushed through the system and undergoes state changes. There are four parts in the refrigeration process.

In the compression stage, the refrigerant enters the compressor as a gas under low pressure and low temperature. Then the refrigerant is compressed adiabatically, so the fluid leaves the compressor under high pressure and with a high temperature. Condensation is the second stage. In this stage, the high-pressure, high-temperature gas releases heat energy and condenses inside the condenser. The refrigerant leaves as a high-pressure liquid. In the throttling stage, liquid refrigerant is pushed through the throttling valve, which causes it to expand. Thus, the liquid refrigerant is now a low-pressure and low-temperature fluid. The last stage is refrigeration. The low-pressure, low-temperature refrigerant enters the evaporator, which is in contact with the cold reservoir. Because a low pressure is maintained, the refrigerant can boil at a low temperature. It moves back into the compressor, and the cycle starts all over again.

Many refrigerators today use the same process as in the 1800s.

Peg A. Lamphier

See also *Vol. 1, Sec. 3*: Perkins, Jacob; *Vol. 2, Sec. 3*: Refrigerator

Further Reading

Ahamed, J., R. Saidur, and H. Masjuki. 2011. "Review on Exergy Analysis of Vapor Compression Refrigeration System." *Renewable and Sustainable Energy Reviews* 15, no. 3, 1593–600.

Zhao, L., W. Cai, X. Ding, and W. Chang. 2013. "Model-based Optimization for Vapor Compression Refrigeration Cycle." *Energy* 55: 392.

Waltham-Lowell Textile System

The Lowell system, also known as the Waltham-Lowell system, was a vertically integrated labor production model implemented in the U.S. textile industry from 1814 to the 1830s. It was developed by Massachusetts-born entrepreneur Francis Cabot Lowell (1775–1817), who had envisioned a highly efficient method of combining the capabilities of many modern inventions of the time (such as the cotton gin, spinning jenny, and water frame) to control all textile production aspects under one roof. Lowell was inspired by an 1811 visit to Great Britain, where he witnessed the products of the Industrial Revolution.

Prior to the advent of the Lowell system, the textile industry of the United States operated by the Slater mill system, or Rhode Island system, modeled by British immigrant William Slater and implemented in Rhode Island in the 1790s. Under this model, mills arose in villages of workers brought in from abroad; often poor, landless families and children. Different villages would specialize in one particular aspect of production: wool was gathered in one village, then sent to another to be spun into cloth. Spinning in the United States was still done with looms powered by foot pedal, as opposed to the power looms in Britain powered by waterwheels.

When Lowell returned from Britain, he and a group of investors called the "Boston Associates" formed the Boston Manufacturing Company in 1813 and opened its first mill along the Charles River in Waltham, Massachusetts, in 1814. This signaled the inception of Lowell's model, a vertically integrated system in which the entire process of textile production—from raw fiber

to finished cloth—was completed within a single location. Combined with power looms modeled after the British system, the result was mass production with a sufficient amount of control to prevent interference in production from outside sources. In fact, the rapidly growing scale of production exceeded the input of localized labor forces available to the mills.

To compensate, Lowell hired young women ages 15 to 35, promising better conditions than those of farm labor. They resided in boardinghouses, were kept to a strict routine overseen by older women, and adhered to a rigid moral code that included mandatory religious service. In an attempt to distinguish his business from the exploitative ones of Britain and Rhode Island, Lowell avoided child labor, paid workers in cash, and provided avenues for his “Mill Girls” to educate themselves.

Lowell died in 1817, and the Lowell system went into decline in the 1830s as cotton overproduction deflated the price for finished cloth, and immigrant labor (fueled especially by the Irish potato famine) replaced the Mill Girls. With the second generation of mill managers lacking Lowell’s idealism, the New England textile industry began resembling its counterparts in Britain and Rhode Island. Lowell is still remembered for his pioneering factory model and for effectively bringing the Industrial Revolution to the United States.

Andres Elvira

See also Cotton Gin; Lowell Mill System; Slater, Samuel; *Vol. 1, Sec. 1: Loom*

Further Reading

Dalzel, Robert F., Jr. 1987. *Enterprising Elite: The Boston Associates and the World They Made*. Cambridge, MA: Harvard University Press.

MacDonald, Alain. 1937. “Lowell: A Commercial Utopia.” *The New England Quarterly* 10, no. 1: 37–62.

Wheel Cipher

The wheel cipher was invented by Thomas Jefferson in 1795 while he was serving as U.S. secretary of state. While the device was likely the most advanced cryptographic instrument of its time, it proved impractical in

everyday use and was forgotten. A version of Jefferson’s invention proved so difficult to decode that it remained in U.S. military use during World War II.

Thomas Jefferson was well acquainted with ciphers and codes; as ambassador to France and then secretary of state, he had been determined to prevent his secret communications from being read. He used the 16th-century Vigenère cipher throughout his career, but he was familiar with many other ciphers, including a wheel-based cipher invented by Leon Alberti in 1467. Jefferson improved this design and created a cipher superior to any other of its time.

The wheel cipher he invented was deceptively simple; it was a series of 36 cylinders with the alphabet and numbers etched along their rims. The cylinders were arranged on a spindle in a random order. Users would then line up the symbols for the letters they wanted to code and pick a separate line. If the reader had an identical device with the cylinders arranged in the correct order, he or she could simply duplicate those characters and look for the line that had plain text.

The wheel cipher was simple to use but virtually impossible to decode. Without the cylinders in correct order, there were 4.7×10^{45} possible combinations. It was a remarkable achievement, one that surpassed virtually any other system of predigital encryption. However, there were drawbacks. In an age before machine tools, the wheel cipher required careful craftsmanship. The final product had to be transported to its destination by courier, and there had to be a system for determining the correct order of cylinders. In 1795, during treaty negotiations with Britain and with a war against France a distinct possibility, Jefferson needed a more practical, if less secure, means of encryption.

As a result of these concerns, Jefferson abandoned his wheel cipher design and embraced a less complex cipher. His first design was forgotten in the archives at Monticello for over a century, but similar devices were reinvented at least twice. In the late 19th century, the French cryptographer Étienne Bazeries created a similar device. The U.S. military’s Col. Parker Hitt independently created a wheel cipher that became known as the M-94. The M-94 was used throughout World War II for tactical communications and is not much

less complex than ciphers still in use by the U.S. military. Jefferson's writings on the wheel cipher were rediscovered shortly after the M-94 entered service in 1922.

James L. Erwin

See also Jefferson, Thomas

Further Reading

Thomson, Keith. 2012. *Jefferson's Shadow: The Story of His Science*. New Haven, CT: Yale University Press.

Weber, Ralph E. 2010. *United States Diplomatic Codes and Ciphers: 1775–1938*. Piscataway, NJ: Transaction.

Primary Document: Excerpts from Thomas Jefferson's Notes on the Wheel Cipher (Undated)

While serving as U.S. secretary of state (1790–1793), Thomas Jefferson devised the wheel cipher, a clever and secure method to encode and decode diplomatic messages. Jefferson had learned, while serving as American minister to France (1784–1789), the importance of encoding his diplomatic correspondence, for European postmasters routinely opened and read all diplomatic messages and any suspect letters passing through their offices. Reproduced here is an excerpt from Jefferson's undated notes on the construction of a wheel cipher.

The Wheel Cypher

Turn a cylinder of white wood about 2 l. diam. and 6. or 8 l. long. Bore through it's center a hole sufficient

to receive an iron spindle or axis of $\frac{1}{2}$ or $\frac{1}{4}$ l. diam. Divide the periphery into 26 equal parts (for the 26 letters of the alphabet) and with a sharp point draw parallel lines through all the points of division from one end to the other of the cylinder and trace those lines with ink to make them plain. Then cut the cylinder crosswise into pieces of about $\frac{1}{6}$ of an Inch thick. They will resemble backgammon men with plane sides. . . .

Source: Thomas Jefferson Papers, Library of Congress.

Whitney, Eli (1765–1825)

Eli Whitney was a late 18th- and early 19th-century American inventor whose work had an incalculable and wide-ranging impact on the development of the United States. While the creative Whitney is credited with a number of inventions that impacted numerous areas of American life, it was his invention of the cotton gin, a device that revolutionized the economy of the American South, that had the greatest impact on the young nation.

Eli Whitney was born on December 8, 1765, in Westboro, Massachusetts, to Eli Whitney Sr. and the former Elizabeth Fay. From an early age, he showed an exceptional instinct for handling mechanical things, demonstrating an uncanny understanding of how they

worked. A big man, he first worked as a blacksmith, but the young inventor and entrepreneur demonstrated an early understanding of markets when he began manufacturing and selling nails to Americans whose previous supply lines from Great Britain had been limited by a series of boycotts and embargoes. Recognizing a consumer desire, he also expanded his manufacturing efforts to include women's hat pins—becoming the only manufacturer in the country of yet another item impacted by trade limits. He was both an astute businessman and a skilled craftsman.

Despite his mechanical skills, Whitney desperately wanted to attend college, an institution that at the time focused on preparing men for either the law or the pulpit. While he professed to want to pursue the law, it was still against his parents' wishes that the young



Though Eli Whitney is most famous for inventing the cotton gin, an apparatus he actually coined with Catharine Littlefield Greene, his most important contribution to American technology is his work with interchangeable parts. (Library of Congress)

inventor attended Yale College, graduating in 1792 at the advanced age of 27. His initial dream of becoming a lawyer was hampered by a lack of money, and in an effort to secure the needed funds, he accepted a position as a tutor in South Carolina. Fortuitously, among the few passengers on the transport carrying Whitney was Mrs. Nathanael Greene, the widow of General Nathanael Greene, the Revolutionary War hero, who was traveling back to her home in Savannah, Georgia, and they became acquainted. Upon arriving in South Carolina, Whitney was greeted with the news that his salary for tutoring would be half of what had been promised. Indignant, he refused the offer and instead accepted an invitation from Mrs. Greene to come to her plantation, read law, and help in whatever way he could the plantation manager, Mrs. Greene's fiancé, Phineas Miller, who was also a Yale alumnus.

Upon arriving at the plantation, it took the astute Whitney little time to recognize the labor problem

inherent in the tedious and inefficient process of extracting fiber from cotton by hand. With the support of Mrs. Greene, he worked during the winter to develop what became the cotton gin. The machine's unveiling, as well as its early demonstrations, were met with an immediate and positive response, and its potential was recognized at once. Indeed, so popular and effective—and so comparatively simple—was the new machine that despite the patent that Whitney ultimately obtained, Whitney and Miller saw little substantive profit, certainly nothing approaching what they had hoped and rightfully anticipated. Indeed, despite a series of legal battles, the machine was pirated, copied, and used all over the South. Ultimately, the primary legal fight over the patents for the cotton gin was settled in 1807, and while Whitney was established as the inventor of the cotton gin—a fact that did bring him considerable fame—the \$90,000 he collected was not a significant reward.

Indeed, he ultimately became so frustrated with the tangle of legal action that he all but abandoned the effort to secure his rights and instead, in severe financial straits, turned his attention to the development of interchangeable parts. With the threat of a possible war with France looming, Whitney got a government contract for 10,000 rifles in 1798. While he was unable to meet the contract in time, he eventually did meet it in amount while also earning another large contract. In the course of fulfilling those orders, he developed his system of interchangeable parts, an idea that did not originate with him but that, befitting his considerable talents as a salesman and marketer, he made commercially practicable. In the end, though, Whitney largely failed to meet his contractual obligations and indeed may have conned government officials into believing he'd accomplished more than he had. Whitney engaged in this duplicitous business practice to financially benefit from the idea of interchangeable parts, in part because he felt he had not been as well compensated for the cotton gin as he deserved.

In addition, while it remains a source of contention among historians, Whitney is often credited with inventing the milling machine, a vital advancement in early 19th-century craftsmanship. In reality, a number of inventors were working on grain-milling machines at the same time in the 1810s, and historians believe that no one person can be credited with the invention.

A longtime bachelor, in 1817, Whitney married the former Henrietta Edwards, the granddaughter of prominent religious leader Jonathan Edwards and a member of a respected Connecticut family. The couple had four children. Whitney died on January 8, 1825, in New Haven, Connecticut. He is buried in the Grove Street Cemetery in New Haven. The cause of death is believed to have been prostate cancer. Ever the inventor, while fighting that disease, he invented and built a number of mechanical devices that were effective in easing the pain, but his family's opposition prevented him from manufacturing any of the items.

Whitney may be one of the most famous of American inventors, but much of the popular history about him and his most famous invention is incorrect or incomplete. Catharine Littlefield Greene remains largely forgotten for her part in the invention of the

cotton gin. History also often fails to record the human misery that the cotton gin created by breathing new life into cotton growing and thus American slavery.

William H. Pruden III

See also Cotton Gin; Greene, Catharine Littlefield; Milling Machine; Slater, Samuel; Waltham-Lowell Textile System; *Vol. 1, Sec. 3: Mechanical Reaper*

Further Reading

Eli Whitney. "PBS: Who Made America?" https://www.pbs.org/wgbh/theymadeamerica/whomade/whitney_hi.html, accessed August 23, 2018.

Green, Constance McL. 1956. *Eli Whitney and the Birth of American Technology*. Boston: Little, Brown.

Whitney, Eli. 2012. *Memoir of Eli Whitney*. Edited by Denison Olmstead. London: Forgotten Books.

Primary Document: Letter of Eli Whitney to His Father Regarding the Ginning of Cotton (1793)

The following is a letter that Eli Whitney wrote to his father in 1793 after his trip to Georgia, where he discerned the difficulty in ginning cotton and began devising a plan for a machine to address the problem. The reader can see young Whitney's confidence in his idea in this letter.

Eli Whitney to Eli Whitney, Senr
New Haven, Sept. 11th, 1793.
Dear Parent,

I received your letter of the 16th of August with peculiar satisfaction and delight. It gave me no small pleasure to hear of your health and was very happy to be informed that your health and that of the family has been so good since I saw you. I have fortunately just heard from you by Mr. Robinson who says you were well when he left Westboro sooner than I now fear will be in my power. I presume, sir, you are desirous to hear how I have spent my time since I left College. This I conceive you have a right to know and that it is my duty to inform you and should have done it before this time; but I thought I could do it better by

verbal communication than by writing, and expecting to see you soon, I omitted it. As I now have a safe and direct opportunity to send by Mr. Robinson, I will give you a summary account of my southern expedition.

I went from N. York with the family of the late Major General Greene to Georgia. I went immediately with the family to their Plantation about twelve miles from Savannah with an expectation of spending four or five days and then proceed into Carolina to take the school as I have mentioned in former letters. During this time I heard much said of the extreme difficulty in ginning Cotton, that is, separating it from its seeds. There were a number of very respectable Gentlemen at Mrs. Greene's who all agreed that if a machine could be invented which would clean the cotton with expedition, it would be a great thing both to the Country and to the inventor. I involuntarily happened to be thinking on the subject and struck out a plan of a Machine in my mind, which I communicated to Miller, (who is agent to the Executors of Genl. Greene and resides in the family, a man of respectability and property) he was pleased

with the Plan and said if I would pursue it and try an experiment to see if it would answer, he would be at the whole expense, I should loose nothing but my time, and if I succeeded we would share the profits. Previous to this I found I was like[ly] to be disappointed in my school, that is, instead of a hundred, I found I could get only fifty Guineas a year. I however held the refusal of the school untill I tried some experiments. In about ten Days I made a little model, for which I was offered, if I would give up all right and title to it, a Hundred Guineas. I concluded to relinquish my school and turn my attention to perfecting the Machine. I made one before I came away which required the labor of one man to turn it and with which one man will clean ten times as much cotton as he can in any other way before known and also cleanse it much better than in the usual mode. This machine may be turned by water or with a horse, with the greatest ease, and one may and a horse will do more than fifty men with the old machine. It makes the labor fifty times less, without throwing any class of People out of business.

I returned to the Northward for the purpose of having a machine made on a large scale and obtaining a patent for the invention. I went to Philadelphia soon after I arrived, made myself acquainted with the steps necessary to obtain a Patent, took several of the steps with Secretary of State Mr. Jefferson agreed to send the Patent to me as soon as it could be made out—so that I apprehended no difficulty in obtaining the Patent—Since I have been here I have employed several workmen in making machines and as soon as my business is such that I can leave it a few days, I shall come to Westboro'. I think it is probable I shall go to Philadelphia again before I come to Westboro', and when I do come I shall be able to stay but few days. I am certain I can obtain a patent in England. As soon as I have got a Patent in America, I shall go with the machine which I am not making, to Georgia,

where I shall stay a few weeks to see it at work. From thence I expect to go to England, where I shall probably continue two or three years. How advantageous this business will eventually prove to me, I cannot say. It is generally said by those who know anything about it, that I shall make a Fortune by it. I have not expectation that I shall make an independent fortune by it, but think I had better pursue it than any other business into which I can enter. Something which cannot be foreseen may frustrate my expectations and defeat my Plan; but I am now so sure of success that ten thousand dollars, if I saw the money counted out to me, would not tempt me to give up my right and relinquish the object. I wish you, sir, not to show this letter not communicate anything of its contents to any body except My Brothers and Sister, *enjoining* it on them to keep the whole a *profound secret*.

Mr. Robinson came into town yesterday and goes out tomorrow, this has been such a bustling time that I have not had opportunity to say six words to him. I have told him nothing of my business—perhaps he will hear something about it from some body else in town. But only two or three of my friends know what I am about tho' there are many surmises in town—if Mr. Robinson says anything about it, you can tell him I wrote you concerning it, but wished not to have it mentioned. I have been considerably out of health since I wrote you last; but now feel tolerably well. I should write to my Brothers and Sister but fear I shall not have time—hope they will accept my good wishes for their happiness and excuse me.

With respects to Mama I am, kind Parent, your most obt. Son

Eli Whitney, Junr.

Source: *The American Historical Review*. Volume 3. New York: The Macmillan Company, 1898, 99–101.

3. Antebellum Industrialization and the Civil War (1820–1865)

OVERVIEW

The 45-year period between 1820 and 1865 was characterized by tumultuous economic, social, and political transformation in the United States. During this time, American industrial and scientific development coincided with the rise of Jacksonian democracy and an emphasis on egalitarian economic independence. The Industrial Revolution was preceded by a rapid increase of population that came as a result of the agricultural revolution; it converged with four distinct moral reform impulses that included the creation of utopian societies (1820), institutional reform (1830s), the abolition movement (1830s), and the early women's rights movement (1840s). An increasing interest in developing educational opportunities for advanced training in applied science, agriculture, and engineering emerged to address the needs of the nation. Perhaps the most significant advancement during this era was the electronic telegraph, since it became the first communications medium to radically break the historic connection between transportation and communication, creating a new industry that transformed information from a personal possession to a global commodity. Industrial interests countered the traditional centering of populist values within the agricultural sector as technological advancements reshaped American economic foundations, enabling the nation to adapt despite a financial panic in 1837 and the first great industrial economic depression that occurred between 1839 and 1843.

Western industrialization was first developed in Europe after Scottish engineer James Watt (1736–1819) developed the double-acting steam engine that fostered factory manufacturing during the late 18th

century. America was not prepared to develop industrial infrastructures until after the War of 1812, because it was still dependent upon Great Britain culturally and economically. The thinking of American economist and publisher Henry Charles Carey (1793–1879) informed American approaches to industrialization. Carey was the son of publisher Matthew Carey (1760–1839), a contemporary of Founding Father Alexander Hamilton (1755–1804), who had earlier been the architect and founder of the American financial system and the first secretary of the Treasury, among many other firsts. Henry Carey took over control of his father's publishing house but made his own mark as a political scientist who promoted laissez-faire, free-trade capitalism. Carey was a proponent of fostering nationally connected, government-protected "associations" for capitalistic production and exchange that advanced Hamilton's work. Hamilton had earlier created a government-backed Bank of the United States that was funded by import tariffs and mobilized a nationwide network of bankers and businessmen friendly to the young "experiment" in democratic government that became known as the Federalist Party. Hamilton had sought to protect government and assist business manufacturing by strategically levying protective duties on foreign-manufactured goods as well as curtailing certain import duties on raw material; Carey leveraged this logic forward through the antebellum period to the Civil War era when he served as Abraham Lincoln's chief economic advisor.

Some of the major inventions came from amateurs; American industrialization would not have occurred without scientific innovators who produced creative visions that motivated entrepreneurs to turn creative imaginings into reality. British physicist and

chemist Michael Faraday (1791–1867), for instance, was considered to be an amateur and had little formal education, yet he discovered benzene and electromagnetic induction, made the first dynamo, and erected a primitive electric motor. Faraday compensated for his lack of mathematical prowess with what Marshall McLuhan called a “fantastic intuition and independence and originality of mind” (McLuhan 1967, 92). But many shifts from enthusiast to professional status occurred in the scientific community throughout the antebellum era. To sustain power in the marketplace, scientists asserted a type of sovereignty by building a “fortress of objectivity”: utilizing scientific rhetoric, they “proved” that their interpretations of the visible universe should govern everyone’s understanding of the world.

Religious Revivals and American Innovation

The Second Great Awakening gained momentum concurrent to the emerging utopian vision that was a reaction to rapid industrialization; it fueled a sensibility that Christianity was the foundation of the egalitarian engine of social progress and set new boundaries for commerce. A dichotomy of thought and action between moral reforms and commercial enterprise created tensions that resulted in a cultural dearth of ideas and ideologies that was destined to culminate in civil war. The American government asserted authority over its continent with the Monroe Doctrine (1823); it also declared that European interference in the Western Hemisphere was dangerous to peace and safety and that the United States would not become involved in European conflicts.

Soon after, mechanics’ institutes were established in urban areas as to educate working men interested in technical subjects and to address society’s need for scientific knowledge. This fostered the field of engineering. Concurrent was the Lyceum Movement in the United States that started in a textile-manufacturing town called Millbury, Massachusetts, in 1826. These institutes were a response to a new class of reader as a result of industrialization, and they created unprecedented access to science and technology information. Men who could not afford subscription libraries could attend lecture courses at lyceums and gain access to

laboratories at mechanics’ institutes. Meanwhile, textile manufacturing created affluence in the Northeast, particularly in Massachusetts. Other forms of manufacturing also became booming industries, including in iron, textiles, and flour mills in the Mid-Atlantic states.

Between 1836 and 1840, the Transcendental Movement arose in the United States, led by thinkers including Frederic Henry Hodge, Ralph Waldo Emerson, Bronson Alcott, Orestes Brownson, Henry David Thoreau, Margaret Fuller, Elizabeth Peabody, and many more. Transcendentalism became the first homegrown American intellectual movement—similar to Romanticism in Europe—that emerged during the late 1820s, when New England thinkers discerned that the institutions of organized religion and political parties could be vectors for corrupting an individual’s innate purity.

Marketplace Innovators

The Industrial Revolution fostered a nation of “creative thinkers” who synthesized and built upon new ideas in the marketplace. These innovators did not have to be *the* actual scientific genius who created the product. The ability to shape a vision around an idea or set of ideas and communicate them to those who would manufacture the product was enough for success. The decade of the 1830s brought about some fundamental building blocks for industrial advancement. Thaddeus and Erastus Fairbanks developed the platform scale, also known as the Fairbanks Scale, in 1830. This bench scale measured the counterbalanced weight of loaded objects at ground level and therefore did not need to use a hoist. Fairbanks scales were the best-known American product in the world by the time the Civil War started. Robert L. Stevens (1787–1856), while president of the Camden & Amboy Railroad, developed the flanged *T* rail in 1831, an all-iron rail that had a flat bottom, requiring no chair to hold it upright. William Otis (1813–1839) invented the steam shovel, a large steam-powered excavating machine designed for lifting and moving material such as rock and soil, typically used in the mining industry, in 1835. The shovel was applied in building railroads. William Austin Burt (1792–1858) developed a solar compass in 1835 with a solar attachment that allowed surveyors to determine the direction of north by reference to the sun rather

than to a magnetic needle. This railroad compass consists of three arcs: one for setting the latitude of the land to be surveyed, one for setting the declination of the sun, and one for setting the hour of the day.

French political writer Alexis de Tocqueville (1805–1859), in *Democracy in America* (1835), observed that Americans tended to be independent, stand-alone citizens who believed that they held their individual destinies in their own hands. Nothing made this more of a reality than communication innovations during the mid-1830s. The penny press became an affordable and economically savvy way to spread information and political views to the masses. The first American daily newspaper was the *New York Herald*. With the telegraph, news could spread like wildfire, conveying opportunities that created instant boomtowns.

Joseph Henry (1797–1878) developed an electrical switch known as a relay that opens and closes under the control of another electrical circuit; this was applied in the electrical telegraph. Alfred Vail (1807–1859) and Samuel Morse (1791–1872) developed a signaling alphabet in 1836 known as Morse code that encoded characters transmitted as telegraphic information using rhythm. Richard Hoe (1812–1886) ignited a revolution in printing by developing the rotary printing press; it prints images by utilizing a curved cylinder. Royal Earl House (1814–1895) developed the printing telegraph in 1846, a derivative of the electrical telegraph that links two 28-key piano-style keyboards by electrical wires corresponding to letters of the alphabet. When a key is pressed, it causes the corresponding letter to print at the receiving end. This is in contrast to the electrical telegraphs that used Morse code's dots and dashes, which needed to be converted into readable text after they were received. After 1850, the printing telegraph was in common use, namely along the United States' East Coast and in France.

These new communications technologies meant that for the first time, communication traveled faster than humans could move. Therefore, the condition of being literate—able to read, write, and be skillful in the use of words—was seminal to sustaining this industrial revolution: only a knowledgeable populace can test and innovate ideas. The notion of “self-education” fostered by literacy went to the core of American cultural

identity that came out of the First Great Awakening: the self-made man. Within the broader idea of “enduring democracy,” where government by the people is exercised either directly or through elected representatives, a populace that is well read and knowledgeable became mandatory. While today literacy does not have a color bar, in the past it did. If any group was intentionally excluded from literacy education, it was effectively disenfranchised. Literacy was tied to identity and became part of the American national identity. Illiteracy within a society reflects an “educational underclass,” with symptoms seen in the disposed of: the homeless, the unemployed, and families on welfare. Economic interests and social control have driven literacy in America: industries with low-skilled workers have not required an educated workforce, but highly skilled jobs require highly literate workers.

Literacy, Standardization, and True Womanhood

Prior to the American Revolution, women were literate enough to teach young children but not enough to challenge male heads of household. During the Early Republic, American Lexicographer Noah Webster (1758–1843) led the movement to standardize the spelling and punctuation of the English language in the United States. He published *The American Spelling Book* (1783) to promote American nationalism and cultural independence from England. In westward expansion, public education was limited, so literacy education occurred at home, in one-room (common) schools, and in church-based education programs. American educator Horace Mann (1796–1859) developed common schools during the antebellum era to support the dramatic cultural changes that were unfolding. Common schools grouped students by grades that employed systematic, mechanical, lock-step teaching of “the three Rs” (reading, [w]riting, and [a]rithmetic), along with history and geography.

Patents provide government license that confers the right or title for a set period of time to exclude others from making, using, or selling an invention in exchange for public disclosure of that invention. The process of patenting was designed so that inventions get explained clearly so that others can build upon the

ideas in them. The value of disclosing an invention's technical details, within the context of patent theory, is that it fosters the prompt inclusion of useful knowledge into the public knowledge banks, reduces research-and-development waste, spurs creative innovation, and leads others to engage with the patentee's work to produce improvements or wholly new innovation, thereby extending industry frontiers.

The Patent Act of 1836 created an official United States Patent Office as part of the Department of State. Politician John Ruggles (1789–1874), during his tenure as a Democratic senator from Maine, served as chairman of the Committee on Patents and the Patent Office and framed a bill to reorganize the Patent Office. (He became known as the “Father of the U.S. Patent Office.”) The act allowed for the efficient processing of patent applications and prevented applications for already patented inventions by requiring information on newly granted patents to be made publicly accessible at libraries throughout the country. Anyone could consult this information to check whether inventions were truly original before filing for a new patent. The act allowed for a possible extension of 7 years of protection in addition to the original 14-year term with the permission of the Commissioner of Patents. It also removed the requirement of U.S. citizenship and residency, making it possible for foreigners to file for U.S. patents. Patent Number 1 was granted to Ruggles on July 13, 1836, for his invention: a type of train wheel designed to reduce adverse effects of the weather on the track.

Capitalism drove American politics as individuals sought opportunities to accumulate wealth continuously. A paternalist aesthetic had historically assumed that husbands, fathers, brothers, and sons would act and make decisions in the best interests of their dependents. A homeless man was considered a dependent just as a slave was; he was not obliged to pay property taxes. If he was clever, he could make his way by bartering services for food and temporary shelter. But the transient, who did not pay taxes, was disenfranchised as well as dependent upon the generosity of others. Those who lived on the fringes of society found themselves in the path of an industrial juggernaut.

At the same time, women's lives were changing, too, according to historian Barbara Welter. She wrote about the “cult of true womanhood”—a sensibility held between 1820 and 1860 that American women were expected to pursue lives of sheltered passivity and ennobled domesticity. In the “private” sphere, middle-class women held authority over moral and family issues and were expected to create an antimaternalistic world within the home that balanced the sordid male world of public life. Emma Willard (1787–1870) established the Troy Female Seminary in 1821 to educate girls to be responsible mothers and to become teachers. Catherine Beecher (1800–1878) wrote her *Treatise on Domestic Economy* (1841) to promote an educational scheme to professionalize female schooling in domestic work in the private, female sphere to mirror masculine training to enter the public, male sphere. Transcendentalist Elizabeth Palmer Peabody (1804–1894) was the first American woman to become a publisher; she had a bookstore in her Boston home from about 1840 to 1852 and edited the Transcendentalist publication called *The Dial* beginning in 1843. Harriet Beecher Stowe (1811–1896) wrote *Uncle Tom's Cabin* (1852), which brought controversial aspects of slavery into popular culture and the nation's consciousness.

Some women began to shift from housework to economically accountable work in textile manufacturing. While men held the management positions in this industry, women and children worked on its production lines. Men earned higher wages in comparison to women, so women were not only paid less but also expected to work unreasonable hours in detrimental conditions with only a few breaks a day. Yet, the textile manufacturing industry served as a gateway to independence for single women, who could become economically self-sufficient, move out of their parents' households, and become somewhat upwardly mobile.

Mechanic Walter Hunt (1796–1859) invented the first lockstitch sewing machine in 1833. In this machine, an upper thread runs from a spool kept on a spindle on top of or next to the machine, through a tension mechanism, a take-up arm, and finally through the hole in the needle. The lower thread is wound onto

a bobbin, which is inserted into a case in the lower section of the machine. Hunt did not apply for a patent to avoid creating unemployment among seamstresses, until Elias Howe (1819–1867) developed the transverse shuttle in 1846 as a method to drive a bobbin on a sewing machine so as to create the lockstitch technique.

Agricultural Innovation and the Challenge of Slavery

Innovations did not confine themselves to urban centers and factory technology. Hiram Moore (1817–1902) invented the first combine harvester in 1834 that combined the tasks of harvesting, threshing, and cleaning grain crops. Blacksmith John Deere (1804–1886) modernized the plow in 1837 by shaping steel from an old sawmill blade and joining it to a wrought-iron moldboard, creating a self-polishing cast-steel plow so that damp soil would no longer stick to it. These inventions revolutionized agricultural work.

The rapid pace of industrialization caused some to worry about what the new type of work did to workers. Transcendentalism provided a powerful counterpoint to antebellum capitalism. New England Transcendentalist Orestes Brownson (1803–1876), in a series of essays called “The Laboring Class,” published in the *Boston Quarterly Review* in 1840, observed during America’s first sustained industrial depression that there was a correlation between motives of capitalists in leadership positions across American industries within the evolving laissez-faire economic model. These capitalists, who controlled the wealth, oppressed the laboring class to a crisis point, and the work ethic of laborers was exploited for the profit of the merchant class. In 1844, another Transcendentalist, Ralph Waldo Emerson (1803–1882), identified the locomotive and steamboat transportation industries as creating a seamless web of American society. The construction of railroads, canals, turnpikes, and steamboats, beyond fostering human mobility, made the transportation of goods more efficient; it created jobs and made travel much easier by connecting the East Coast to the West Coast.

John L. O’Sullivan coined the phrase “manifest destiny” in 1845, asserting that it is the “right of our

manifest destiny which Providence has given us for the great experiment of liberty and federated self-government entrusted to us.” Direct democracy and its checks and balances tested the capabilities of the more malleable society composed of diverse interest groups, each with their agendas.

Meanwhile, in Europe, with such dramatic technological change, unskilled workers faced 12- to 15-hour days—when they could find employment—and lived in disease-ridden slums. Artisans lost their guilds; they were crushed by the industrial juggernaut. Subsequent to several harvest failures, urban workers spent about half of their incomes on food—which primarily consisted of bread and potatoes. This led to a series of failed European revolutions in 1848 led by coalitions of reformers, the struggling middle class, and workers. Conversely, the American middle class was the fastest-growing group during the antebellum period. Immigrants and female factory workers were occupied in harsh and dangerous conditions with low wages. These groups were only offered work as cheap labor. Nativists—those who sought to protect the interests of native-born inhabitants against those of immigrants—became hostile toward immigrants, whom they perceived as taking jobs from Americans. The Know-Nothing Party emerged as part of the Nativist reaction to immigration.

At the start of the Civil War, less than 5 percent of Americans of African descent were literate. The South was still based economically on agricultural advancements because of the free labor and fertile soil. Slavery appeared to be primarily focused in the South by 1830; however, Native American women could legally be indentured—sold into slavery—if captured, a practice that continued until the Civil War. African Americans were enslaved on small farms, large plantations, in cities and towns, inside homes, out in the fields, and in industry and transportation.

Charles Carey published *The Harmony of Interests: Agricultural, Manufacturing, and Commercial* (1851), which described an American sensibility of developmental capitalism that utilized tariff protection and government intervention to encourage production and national self-sufficiency. Carey was a proponent of the ideal of harmony of interests among

agriculture, manufacturing, and commerce. He felt that government intervention was necessary to foster industry in younger, experimental communities created by the actions of older and wealthier nations. In Carey's later work, *The Principles of Social Science* published in three volumes, he sought to show that independent of human will, a natural system of economic laws exists that can increase the prosperity of the community, especially in the working classes, except when it is impeded by the ignorance of humankind.

Yet in the pre-Civil War South, enslaved people were considered property. This status was enforced by violence; beyond this, they were considered to be dependents. The Dred Scott legal decision (1857) ruled that African Americans had no claim to freedom or citizenship; they were considered property and therefore could not bring lawsuits or testify against those classified as white in court. Therefore, the power imbalance under the Southern plantation economy grew. Nonslaveholding white Southerners identified with and eventually defended the institution of slavery although many resented the wealth and power of the large slaveholders. Slavery provided poor farmers a sense of power and entitlement simply because they were classified as white. They might have been poor, but they were not enslaved, and they were not of African descent.

Gold Rush Failures

The economics of the California Gold Rush (1848–1855) blended capitalism, individualism, and early forms of futures speculation. The estimated \$2 billion in gold extracted from California soil stimulated a tumultuous global economy. The U.S. government awarded the Pacific Mail Steamship Company, established in 1848 as a joint stock company, exclusive rights to transport mail via the Isthmus of Panama to California, creating a communications monopoly. San Francisco became a hub for inept capitalism and greed that actually disbursed wealth to other regions of the globe during 1848, the “year of failed revolutions.” Ordinary men squatted and remained disenfranchised when they could not acquire land through legitimate means. Felice Argenti (1802–1861), a patriot of the

Risorgimento from Viggiù in Lombardy (known by his Americanized name, Felix Argenti), operated the largest bank in San Francisco before Wells Fargo was established in 1852. Argenti charged high “loan shark” interest rates. California banks were not regulated until the State Revenue Act, passed May 18, 1853, levying 10 cents for every \$100 of business transacted, so speculators like Joseph Libbey Folsom (1817–1855) purchased and developed land utilizing credit lines and sometimes dubious means.

Antebellum industrialization could bring about rough sport. Politics dictated who controlled resources and the circumstances by which California entered the Union in 1850 at the peak of the Gold Rush boom. Individuals involved with slavery (which gave Southern white males an unfair advantage in the goldfields) were challenged based on the assumption that control of property and labor impacted political agency. The Fugitive Slave Act, or “Compromise of 1850,” included concessions to pro-slavery forces needed to gain the admission of California to the Union. This Act created an infrastructure to capture escaped slaves living in free territories yet often freeborn individuals of African ancestry not carrying freedom papers could be seized and sold into slavery. Slave owners were permitted to travel through free states, including California, with slaves (considered to be servants), but if a slaveholder resided there, then their slaves could leave. Throughout the 1850s, the California Legislature attempted to limit African American migration into the state with unsuccessful anti-immigration bills introduced in 1851, 1855, and 1858.

Alabama attorney Solomon Heydenfeldt (1816–1890) wrote a controversial opinion about the impact of slavery on the Southern economy, “A Communication on the Subject of Slave Immigration,” in 1849. He opposed the immigration of slaves to Alabama, not as an abolitionist but as a pragmatist who viewed slave labor as unproductive because it inhibited industrialization. Heydenfeldt's minority view made him very unpopular; he was compelled to leave his home state and arrived in San Francisco in 1850, where he joined the law firm of Shafter, Shafter, Park and Heydenfeldt. Two years later, Heydenfeldt was the first Jewish person elected to serve on the California Supreme Court by a popular vote.

The adage “out of sight, out of mind” goes to the core of California economics that pushed ethical boundaries in the absence of oversight from the federal level; on this frontier, industry was slow coming. Those who speculated on land also speculated on maritime futures, essentially wagering on whether cargo would make it to destinations on time and complete—because mariners were abandoning ships to go to the goldfields. To keep commerce moving, local governments and leading commission merchants turned a blind eye to an emerging shanghai industry operating along the Pacific Coast. Any man would walk into a bar and be offered liquor or cigars laced with narcotics to induce a dozen hours of sleep—just long enough to find himself thrust into involuntary servitude on the high seas.

In this predatory ecosystem, women provided practical domestic industries cheaper than white men, but not men of color. The California Legislature passed “an Act to authorize married women to transact business in their own name as sole traders” on April 12, 1852. Married women could earn money for domestic tasks with limited guidance or control from husbands. This Act was not intended to give women financial independence within marriage but rather to bring a temporary infusion of domesticity to the wild economic winds of speculation that brought misfortune to California communities. Married women registered business plans, allowing husbands to formally invest and shelter up to \$5,000 in their enterprises. Women then developed properties on landfill acreage along a waterfront reconfigured with the latest technology, a waterfront that is now in the heart of San Francisco’s business district, and Heydenfeldt’s opinions would expand married women’s property rights.

Civic leaders believed they were carving out a just and rational order out of the chaos of America’s last frontier. Elected by miners with a working-class political agenda, delegates to the first California Constitutional Convention (1849) many quickly discerned that race was integral to the miners’ egalitarianism. West Coast workers converted this rhetoric into a potent political platform. San Franciscans established their own Mechanics’ Institute in 1854 as work in the goldfields slowed and advances in mining technology required more advanced partnerships. The Mechanics’

Institute was considered to be a landmark in California technical training until the University of California was established in 1868. Freeborn entrepreneur of African ancestry Mifflin Wistar Gibbs (1823–1915), who obtained an education from the Mechanics’ Institute, became a respected businessman in Gold Rush San Francisco and was among the signers on a petition opposing a ban on blacks testifying against whites. He was among the founders of the first formal African American political action group in California, known as the Franchise League of San Francisco.

“Fast Food” for a Mobile Population

During the War of 1812, the concept of canned food had been introduced in the United States. New Yorker Robert Ayars established the first American canning factory in 1812, using improved tin-plated wrought-iron cans for preserving oysters, meats, fruits, and vegetables. Demand for canned food greatly increased during wars—especially during the Civil War—when working-class men on the front were introduced to canned food. Canning companies expanded their businesses beyond military demands for nonperishable food, selling it to wider civilian markets after wars ended.

Inspired by the California Gold Rush, Gail Borden III (1801–1874) experimented with the idea of producing a dehydrated beef product known as the “meat biscuit,” which was loosely based upon a traditional Native American food called pemmican. Pioneers needed a readily transportable food source that could endure harsh conditions, and Borden marketed the meat biscuit to miners as a suitable solution. Borden invented condensed milk in 1856—cow’s milk from which water is removed and to which sugar is added, yielding a very thick, sweet product that can last for years without refrigeration if unopened. Soldiers used condensed milk during the American Civil War.

John Landis Mason (1832–1902) invented a reusable square-shouldered jar in 1858, which had a threaded screw top, matching lid, and rubber ring for an airtight seal. Before refrigeration and hothouse gardens, many fruits and vegetables had been available only seasonally, but the development of these jars made canning a practical alternative to drying, pickling, or

smoking to preserve food. Prior to Mason's innovation, preserving food in jars—under a layer of wax—had been messy, unreliable, and unsafe.

California gold would finance the Union during the Civil War. The war brought about new technologies: chief gunsmith and designer for Oliver Fisher Winchester's arms company, Benjamin Tyler Henry (1821–1898), adapted a breech-loading rifle in 1860 first designed by Walter Hunt. Union soldiers in the Civil War made the Henry rifle as famous as the Winchester. A movement toward "portability" shaped the business of war, and new gimmicks were developed to sell merchandise.

William Bullock (1813–1867) invented the rotary printing press in 1865; it could feed paper on a continuous roll and print both sides of the paper at once. Richard Gatling (1818–1903) had earlier patented a number of inventions, including a screw propeller (1839), a wheat drill-planting device (1839), and a steam-plow tractor (1857). While the introduction of Gatling's planting machines revolutionized the agricultural system in the United States, during the Civil War, he developed a gun based upon his seed planter that became the earliest precursor to the machine gun.

In science, demography (the study of human populations, including size, growth, density, distribution, and vital statistics), ecology (the science of relationships between organisms and their environments), and economics (the science of production, development, and management of material wealth) became interconnected. The evolution of science within such a context would eventually reduce the autonomy of scientists, who would become dependent upon institutions that could offer substantial capital investments for researching and developing ideas. After the Civil War, the professional scientist would become the innovator of ideas, concepts, and sensibilities. While scientists generate creative ideas that become the basis of innovations, not all of them are scientific leaders like Thomas Alva Edison (1847–1931), who would go beyond devising a commercially viable electric lightbulb—he also developed a utility for distributing electricity itself.

Meredith Eliassen

Further Reading

- Cutcliff, Stephen H., and Terry S. Reynolds. 1997. *Technology and American History: A Historical Anthropology from Technology and Culture*. Chicago: University of Chicago Press.
- Evans, Charles M. 2002. *The War of the Aeronauts: A History of Ballooning during the Civil War*. Mechanicsburg, PA: Stackpole Books.
- Greif, Anver, Lynne Keising, and John V. C. Nye. 2015. *Institutions, Innovations, and Industrialization: Essays in Economic History and Development*. Princeton, NJ: Princeton University Press.
- Hasegawa, Guy R. 2012. *Mending Broken Soldiers: The Union and Confederate Programs to Supply Artificial Limbs*. Carbondale: Southern Illinois University Press.
- Hawke, David Freeman. 1988. *Nuts and Bolts of the Past: A History of American Technology, 1776–1860*. New York: Harper & Row.
- Kane, Joseph Nathan. 1997. *Necessity's Child: The Story of Walter Hunt, America's Forgotten Inventor*. Jefferson, NC: McFarland.
- Lakwete, Angela. 2005. *Inventing the Cotton Gin: Machine and Myth in Antebellum America*. Baltimore: Johns Hopkins University.
- McLuhan, Marshall, and Quentin Fiore (produced by Jerome Agel). 1967. *The Medium Is the Message*. New York: Touchstone.

Adhesive Tape

Adhesive tape is a roll of backing material coated with a form of adhesive, used for sticking different objects together. Different backing materials and adhesives are used depending on the use of the tape.

Adhesives are substances that can hold two materials together. Usually adhesives are permanent. Natural adhesives include beeswax, resin, and bitumen. Ancient Egyptians used adhesives made from animal skin and bones. Medieval monks used egg white to bind gold leaf to their manuscripts. In the 19th century, rubber became a popular adhesive.

The first adhesive tape was made in 1845 by London surgeon Dr. Horace Day, who used a rubber

adhesive applied to strips of fabric to pioneer surgical tape. In 1882, a German pharmacist named Paul Beiersdorf invented an adhesive bandage. The next real advances in adhesive technology came in the 20th century, when synthetic materials were industrialized.

Perhaps the most famous adhesive tape/bandage was invented in 1921 by Earle Dickson, who improved on Horace Day's surgical tape by applying a piece of gauze to a cloth-backed tape and covering it with crinoline, creating what is now well known as the Band-Aid. The Band-Aid was created because Earle Dickson's wife, Josephine, frequently cut herself during cooking. The prototype Band-Aid allowed her to dress her wounds.

In 1923, Richard Drew created the world's first masking tape to help auto painters working in an auto body shop make clean dividing lines on a two-color paint job. Drew would later create Scotch tape from the same masking tape used in the auto shops. Scotch tape was named after Drew's Scottish boss from back when he worked for the 3M Company.

In 1942, the Revolite division of the Johnson & Johnson Company invented duct tape. During World War II, the troops needed a waterproof tape that was durable and useful for repairs: Johnson & Johnson coated a roll of cloth tape with polyethylene.

In the 21st century, there is a multitude of different types of adhesive tape made for different uses. Duct tape continues to be useful for taping air-conditioning ducts due to its durability and long life, but millions of Americans have a variety of uses for it. Gaffer tape is designed for film and camera production to temporarily hold things in place. Its adhesive is more resistant to heat and more easily removed without damaging surfaces. Packing tape used for postage is lighter and, therefore, cheaper. It tends to be thin and strong, but the adhesive only has to resist pulling sideways (a.k.a. "shear load"). Masking tape helps artists and painters, stopping paint from leaking under it and coming off cleanly afterward. Here, the strength of the adhesive and tape are much less important. Electrical tape must be a good insulator against electricity and should have a long life.

Warod Changpradith

See also Vol. 2, Sec. 2: Band-Aid; Scotch Tape



Making wallets out of duct tape became a trend in and around 2011, with Keith Drone of Nashville, Tennessee, claiming to be the father of the fad. Adhesive tape came out in 1845, when Doctor Horace Day invented it as a way to bandage surgical patients. Today surgeons use a form of super glue instead. (Bill Hogan/Chicago Tribune/MCT via Getty Images)

Further Reading

Finger, Kirsten. 2005. *Tape: An Excursion through the World of Adhesive Tapes*. Berlin: Gestalten Verlag.

Agassiz, Louis (1807–1873)

Louis Agassiz was a Swiss-born American naturalist and geologist. Known for his research on extinct fishes and glacier activity, Agassiz was a professor of zoology and geology at Harvard University and served as founding director of Harvard's Museum of Comparative Zoology. He was a staunch opponent of Darwin's theory of evolution.

John Louis Rudolph Agassiz was born in 1807 in Môtiers, Switzerland, to Rodolphe Agassiz, a Protestant minister, and Rose Mayor. As a young man, he studied at the universities of Heidelberg, Munich, and Erlangen, earning a PhD in 1829 and an MD in 1830.

His mentors included French comparative anatomist Georges Cuvier, a proponent of the idea that the extinction of species was a fact. In 1832, with the patronage of geographer Alexander von Humboldt, Agassiz was appointed a professor at the College of Neuchâtel. The following year, he married Cécile Braun, with whom he had three children.

Between 1833 and 1843, Agassiz published a series of studies called *Poissons fossiles*, a comprehensive exploration of more than 1,700 prehistoric fishes. This pioneering work established Agassiz's reputation in the scholarly community and suggested that intelligent design led to the creation of multiple, distinct species. In 1837, Agassiz was the first scientist to apply glacial theory to all of Europe, expanding ideas first suggested by Swiss naturalist Jean de Charpentier. His *Études sur les glaciers* (1840) and *Système glaciaire* (1847) became important works in the study of the ice age in Earth's northern hemisphere.

In 1846, Agassiz sailed alone to the United States to study the flora and fauna of the Americas. He spent the winter of 1846–1847 in Boston, lecturing at the Lowell Institute, and was then offered a three-year appointment as a professor of zoology and geology at Harvard's Lawrence Scientific School in 1847. After Cécile's death from tuberculosis in 1848, Agassiz decided to remain in Boston. In 1850, he married Elizabeth Cabot Carey, an intelligent and well-connected Bostonian. She was an ardent promoter of women's education, and she operated a school for young women at the Agassiz home from 1855 to 1863.

Agassiz encouraged Harvard to establish a natural history museum that could serve to educate the public and train graduate students. The Museum of Comparative Zoology opened in November 1859. Agassiz continued to search for new species to fill his museum, as well as creatures that would provide evidence of creationism. In 1865–1866, Louis and Elizabeth traveled to Brazil as part of an expedition funded by Boston banker Nathaniel Thayer. They collected over 34,000 species for the museum and authored a popular account of their voyage, *A Journey in Brazil*, in 1868.

Agassiz's reputation suffered toward the end of his career as he continued to promote creationism over Darwin's theory of evolution. He supported the view that different races of humans were different species, which lent credibility to those promoting scientific racism and sexism, although Agassiz did not support racial or gender inequality. Agassiz passed away on December 14, 1873.

Kathleen Barker

See also *Vol. 1, Sec. 1*: Franklin, Benjamin; Natural History; Rittenhouse, David; *Vol. 2, Sec. 2*: Dickerson, Mary Cynthia

Further Reading

Irmscher, Christoph. 2013. *Louis Agassiz: Creator of American Science*. Boston: Houghton Mifflin Harcourt.

Primary Document: Excerpt from the Journal of Louis Agassiz Describing a Trip to the United States (1846)

In 1846, Louis Agassiz, who divided much of his life between the United States and Europe, left Paris and traveled to the United States. The following is an excerpt from his journal, wherein he describes his American experience.

BOSTON, December, 1846.

Having no time to write out a complete account of my journey of last month, I will only transcribe for you some fugitive notes scribbled along the road in

stages or railroad carriages. They bear the stamp of hurry and constant interruption.

Leaving Boston the 16th of October, I went by railroad to New Haven, passing through Springfield. The rapidity of the locomotion is frightful to those who are unused to it, but you adapt yourself to the speed, and soon become, like all the rest of the world, impatient of the slightest delay. I well understand that an antipathy for this mode of travel is possible. There is something infernal in the irresistible power of steam,

carrying such heavy masses along with the swiftness of lightning. The habits growing out of continued contact with railroads, and the influence they exert on a portion of the community, are far from agreeable until one is familiar with them. You would cry out in dismay did you see your baggage flung about pell-mell like logs of wood, trunks, chests, traveling-bags, hat-boxes, all in the same mill, and if here and there something goes to pieces no one is astonished; never mind! we go fast,—we gain time,—that is the essential thing.

The manners of the country differ so greatly from ours that it seems to me impossible to form a just estimate regarding them, or, indeed, to pronounce judgment at all upon a population so active and mobile as that of the Northern States of the Union, without having lived among them for a long time. I do not therefore attempt any such estimate. I can only say that the educated Americans are very accessible and very pleasant. They are obliging to the utmost degree; indeed, their cordiality toward strangers exceeds any that I have met elsewhere. I might even add that if I could complain of anything it would be of an excess, rather than a lack, of attention. I have often found it difficult to make it understood that the hotel, where I can work at my ease, suits me better than the proffered hospitality . . .

But what a country is this! all along the road between Boston and Springfield are ancient moraines and polished rocks. No one who had seen them upon the track of our present glaciers could hesitate as to the real agency by which all these erratic masses, literally covering the country, have been transported. I have had the pleasure of converting already several of the most distinguished American geologists to my way of thinking; among others, Professor Rogers, who will deliver a public lecture upon the subject next Tuesday before a large audience.

A characteristic feature of American life is to be found in the frequent public meetings where addresses are delivered. Shortly after my arrival in Boston I was present at a meeting of some three thousand workmen, foremen of workshops, clerks, and the like. No meeting could have been more respectable and well-conducted. All were neatly dressed; even the simplest laborer had a clean shirt. It was a strange sight to see such an assemblage, brought

together for the purpose of forming a library, and listening attentively in perfect quiet for two hours to an address on the advantages of education, of reading, and the means of employing usefully the leisure moments of a workman's life. The most eminent men vie with each other in instructing and forming the education of the population at large. I have not yet seen a man out of employment or a beggar, except in New York, which is a sink for the emptyings of Europe. Yet do not think that I forget the advantages of our old civilization. Far from it. I feel more than ever the value of a past which belongs to you and in which you have grown up. Generations must pass before America will have the collections of art and science which adorn our cities, or the establishments for public instruction, sanctuaries as it were, consecrated by the devotion of those who give themselves wholly to study. Here all the world works to gain a livelihood or to make a fortune. Few establishments (of learning) are old enough, or have taken sufficiently deep root in the habits of the people, to be safe from innovation; very few institutions offer a combination of studies such as, in its ensemble, meets the demands of modern civilization. All is done by the single efforts of individuals or of corporations, too often guided by the needs of the moment. Thus American science lacks the scope which is characteristic of higher instruction in our old Europe. Objects of art are curiosities but little appreciated and usually still less understood. On the other hand, the whole population shares in the advanced education provided for all . . . From Springfield the railroad follows the course of the Connecticut as far as Hartford, turning then directly toward the sea-coast. The valley strikingly resembles that of the Rhine between Carlsruhe and Heidelberg. The same rock, the same aspect of country, and gres bigarre* (*Trias.) everywhere. The forest reminds one of Odenwald and of Baden-Baden. Nearer the coast are cones of basalt like those of Brissac and the Kaiserstuhl. The erratic phenomena are also very marked in this region; polished rocks everywhere, magnificent furrows on the sandstone and on the basalt, and parallel moraines defining themselves like ramparts upon the plain.

Source: Agassiz, Elizabeth Cary, ed. 1885. *Louis Agassiz: His Life and Correspondence*, vol. II. Boston: Houghton, Mifflin and Company, 409–13.

Anesthesia

Anesthesia is a state of mind and body marked by unconsciousness, loss of memory, relaxation of the muscles, and absence of pain sensation. Many substances are capable of rendering part or all of the symptoms associated with anesthetics; however, the modern “general anesthesia” delivered by inhalation or injection can be traced to the middle of the 19th century. Anesthetics are commonly used as an aid in medical procedures and are intended to render the patient calm and unresponsive before, during, and after a surgical procedure rather than exerting any direct medicinal or curative power. Those who study and practice the administration of anesthetics are anesthesiologists, and their field is anesthesiology—an important area in modern surgery.

Broadly construed, there are three types of anesthesia: general, dissociative, and regional. General anesthesia suppresses the central nervous system, causing lack of consciousness and sensation. A dissociative anesthetic (commonly called a sedative) inhibits nerve function and long-term memory but allows the patient to remain conscious. Finally, a regional anesthetic blocks the receptors of a particular part of the body from the rest of the nervous system. Each of these three varieties has applications for general medicine, surgery, dentistry, and therapeutics, among other disciplines.

There were attempts to discover a general anesthetic among the ancient Egyptians, Greeks, and Romans, as well as the Chinese. The surgical use of alcohol, opium, carbon monoxide, and even ice were all proposed with subjective criteria for success. It is largely agreed that two major breakthroughs of the late 18th and early 19th centuries made the advent of modern anesthetics feasible. British polymath Joseph Priestley’s experiments isolating nitrous oxide and other gases led to greater interest in “inhalable gases” as therapeutic options during the late 18th century. Further, in 1804, German pharmacist Friedrich Sertürner derived morphine from the opium poppy, isolating its powerful, addictive sedative.

News of these European discoveries was widely disseminated among academics in the United States, who witnessed the recreational “ether frolics” performed

by traveling purveyors to members of their audience for the amusement and edification of onlookers. In 1842, William Edward Clarke and William T. G. Morton, both undergraduates at Berkshire Medical College in Vermont, used ether as part of a dental extraction. Later that year, Crawford W. Long, a pharmacist and physician in Jefferson, Georgia, used ether when removing a tumor from the neck of a man named James Venable. While both of these occurrences demonstrate the interest that a rising generation of medical students took in general anesthetics, neither man chose to immediately publicize his actions.

Anesthesia continued to be used sporadically and experimentally by individual American practitioners. In 1844, Horace Wells, a Connecticut dentist, had a tooth removed with nitrous oxide by fellow dentist Gardner Quincy Colton. William T. G. Morton was at that time a business associate of Wells, and he arranged for his partner to publicly demonstrate his procedure at the Massachusetts General Hospital in Boston. This demonstration failed when the patient cried out in pain halfway through the procedure, and it failed to make the public relations impact that Morton desired.

Morton would be the first to successfully and publicly demonstrate the administration of general anesthetic during a surgery on October 16, 1846, in the posthumously titled “Ether Dome” operating theater of the Massachusetts General Hospital. Morton administered the anesthesia while Harvard doctor John Collins Warren removed a tumor from a patient. After the surgery was completed, Warren reportedly said, “Gentlemen, this is no humbug!” His demonstration was celebrated in the painting *First Operation under Ether* by Robert C. Hinckley, and other procedures were shown through the emerging medium of photography as a milestone in American medicine. Charles Thomas Jackson, a professor at Harvard University, later claimed that Morton had stolen the concept from him. Crawford Long, whose work in Georgia went unnoticed, also contested Morton’s claim as far as the floor of the U.S. Senate. These disputes lasted for the entire lifetime of the participants and have not been satisfactorily resolved even to this day. Massachusetts General Hospital continues to celebrate “Ether Day” in commemoration of Warren and Morton’s public demonstration.

Starting in the 1850s, chloroform (an organic compound derived from marine seaweed) gained in popularity as an anesthetic over ether both in the United States and Europe. This pattern was reversed in favor of ether once again after chloroform was found to have adverse cardiac health effects. Anesthetics gained steady acceptance among the medical community; however, specialization in administering it was not common until the 20th century. The first department of anesthetics was not established in the United States until 1936, when one was formed at the Massachusetts General Hospital.

At the turn of the 20th century, the majority of surgical anesthetics were inhaled, applied locally, or given intravenously (injected directly into the veins). These methods were not suitable for some surgical procedures, as there remained a great risk of blood and mucus buildup, which could threaten breathing. In 1913, American physician Henry Janeway developed tracheal intubation (the placement of a tube inside the air passage of a patient) and combined it with an inhaled anesthetic. Intratracheal anesthesia became commonplace in American hospitals and continued to develop during the 20th century. By the 21st century, small cameras could be used to maneuver the tube into place.

The first intravenous anesthetic, sodium thiopental, was created by Ernest H. Volwiler in 1934 at Chicago's Abbott Laboratories. At the time, lab scientists were busy finding a substitute for morphine-based anesthetics, which had dangerous addictive properties. The discovery of meperidine in 1939 and methadone in 1947 provided viable alternatives that possessed the same pharmacological benefits as traditional morphine derivatives.

New anesthetics and technologies continue to develop into the 21st century as surgical procedures become more intricate and specialized, while new alternatives to traditional anesthetics continue to be developed to respond to new needs and health care environments. Once prohibitively expensive, xenon gas has become a viable option because of advances in distribution technology and recycling.

Sean P. Phillips

See also Civil War Medicine; Civil War Nursing

Further Reading

- Fenster, Julie. 2002. *Ether Day: The Strange Tale of America's Greatest Medical Discovery and the Haunted Men Who Made It*. New York: Harper Collins.
- Snow, Stephanie J. 2009. *Blessed Days of Anaesthesia: How Anaesthetics Changed the World*. Oxford: Oxford University Press.
- Sykes, Keith. 2007. *Anaesthesia and the Practice of Medicine: Historical Perspectives*. Boca Raton, FL: CRC Press.

Ball Bearings and Babbitt Metal

Ball bearings are simple components that allow mechanisms with rotating parts to move freely and with little friction. The common ball bearing is constructed from two rings and a number of small metal balls; thus the name “ball bearing.” One ring is large enough to contain the second ring with space in between, and the space is filled with the bearing balls. The balls allow the top ring to move around the bottom ring, with the only friction being from the small space where each ball touches the rings. The ball bearing is limited in strength only by what the small bearing balls can withstand while still fulfilling their function—which is why the alloys that make bearing balls, called “Babbitt metals,” are so important.

Babbitt metal is a kind of soft metal that wears easily, with an inner structure of hard crystals. The softer metal can therefore wear away and make paths for a bearing to pick up lubricants. Babbitt metals are resistant to “galling,” which is when material from one metallic surface becomes friction welded to another, causing tearing of the crystal structure as well as buildup that leads to additional wear. Most Babbitt metals are alloys of tin or lead, with tin alloys being more common in systems such as automotive engines. Lead bearings are used where constant turning motion is present, such as with saw blades. The tin in Babbitt alloys melts partially, protecting the bearing in situations where there is no lubricant. Because lead-based alloys tend to work harden, Babbitt metals made from lead can develop cracks.

Isaac Babbitt, who developed the first Babbitt metal, was born on July 26, 1799, in Taunton,



Ball bearings, seen here in production at the SKF Industries factory, are used to reduce rotational friction and support radial and axial loads. (Lofman/Pix Inc./The LIFE Images Collection/Getty Images)

Massachusetts. He trained as a goldsmith and was responsible for creating the first Britannia ware in the United States, a specific type of pewter alloy, popular due to its silvery smooth surface. He partnered with William Ware Crossman to form Babbitt & Crossman in May 1824. He worked for the South Boston Iron Company as a superintendent and was also responsible for creating the first brass cannon in the United States. In 1839, he created the first Babbitt metal, an alloy of copper and antimony in a soft mixture of tin. The patent for his metal states that it is for “a new and improved mode of making or constructing [machinery bearings] . . . by which . . . the heating and abrasion which are apt to occur . . . are prevented.” Congress

awarded him \$20,000 by for the invention. Thereafter, he manufactured his alloy as well as soap. He died on May 26, 1862, in Somerville, Massachusetts.

Tom Conrad Landry

See also *Vol. 1, Sec. 1: Iron- and Silversmithing; Vol. 1, Sec. 2: Internal Combustion Engine*

Further Reading

Hess, Henry. 2016. *Ball Bearings: Design Construction Mounting*. London: Forgotten Books.

Whitmore, H. L. 1921. *Friction and Carrying Capacity of Ball and Roller Bearings*. Washington, D.C.: National Bureau of Standards.

Best Friend Steam Engine

Some scholars call *The Best Friend of Charleston* the first locomotive built in America; other historians qualify the statement by saying it was the first locomotive built for sale to a railroad, to distinguish it from some earlier ones built by experimenters and designers.

In 1830, the South Carolina Canal and Rail Road Company, which had been chartered to build a line from Charleston to Hamburg, South Carolina, on the Savannah River, ordered a steam locomotive from the West Point Foundry in New York State. The railroad had hired one of America's leading steam locomotive experts, Horatio Allen (1802–1889), to aid in the design of this locomotive. When finished, the locomotive, which cost \$4000, was shipped by boat, disassembled, and delivered to Charleston on October 23, 1830. Personnel of the railroad assembled and tested it. In the early days of American railroading, locomotives were often given names, and this engine was christened *The Best Friend of Charleston* because local businessmen believed it would help boost commerce in the region.

On Christmas Day, 1830, *The Best Friend* pulled a two-car passenger train over six miles of track. Since the excursion had been announced in a newspaper the previous day, this was the first scheduled passenger train operation in the United States. A report in a Charleston newspaper later said that the train “annihilated time and distance” by travelling at what was then the remarkable speed of 15 to 25 miles per hour.

Unlike what most people likely think of as a typical locomotive, which has a long, horizontal boiler parallel to the track, *The Best Friend* had a vertical boiler. The steam it produced powered two cylinders that turned a crank, transferring power to all four wheels. Thus, all four wheels were powered drivers, and while the locomotive was diminutive, these wheels stood four and a half feet tall. The locomotive weighed about four and a half tons and ran on a five-foot track gauge. Gauges wider than the standard gauge in use today (which is four feet, eight and a half inches) were common in the early days of American railroading. Like many early locomotives, it had no cab to protect the engineer and fireman from the elements.

While it operated successfully in regular service for about six months, *The Best Friend* came to an early

and tragic end. On June 17, 1831, a fireman tied down the safety valve, which was designed to allow excess steam to escape safely. He might have done this to stop the noise the valve produced, or perhaps he believed that disabling it would give the locomotive more power. The result was the first locomotive boiler explosion in the United States, which killed the fireman—making it also the first recorded railroad accident in America with a fatality. For a time, when operating passenger trains with other locomotives, the South Carolina Railroad placed a flatcar loaded with cotton bales between the locomotive and the first passenger car in an attempt to allay passengers' fear of harm from a boiler explosion. Within three years, the South Carolina Railroad was operating six locomotives, and when its line was completed to the Savannah River in 1833, it was, at 136 miles, the longest railroad in the world.

A few years later, parts of *The Best Friend* were used to build a new locomotive in the South Carolina Railroad's shops. This locomotive was named *The Phoenix*, and it continued in service until shortly before the Civil War. The South Carolina Railroad was eventually absorbed into the Southern Railway, and in 1928, the Southern built an operable replica of *The Best Friend* to commemorate the centennial of the building of the South Carolina Railroad.

Today, the Southern Railway is part of the Norfolk Southern Railway, and in the early 2000s, the Norfolk Southern refurbished *The Best Friend* at the railroad's shops in Chattanooga, Tennessee. Today, this replica is at the Best Friend of Charleston Museum in Charleston, South Carolina. Another replica can be seen at the South Carolina State Museum in the state's capitol city, Columbia.

Mark S. Joy

See also Railroad T-Rail and Tie; Railroads; *Vol. 2, Sec. 1: Railroad Refrigerator Car; Railroad Sleeping Car and Pullman Car*

Further Reading

Best Friend of Charleston. www.bestfriendofcharleston.org, accessed August 22, 2018.

White, John J., Jr. 1997. *American Locomotives: An Engineering History, 1830–1880*. Baltimore: Johns Hopkins University Press.

Breast Pump

On June 20, 1854, the U.S. Patent Office issued Patent No. 11,135 to Orwell H. Needham, a physician and inventor in New York, for a breast pump that used vacuum technology to help women express breast milk. Needham's creation was an improvement over earlier machines. He had devised an apparatus that used tubing to connect a small, hand-pumped bellows to a flexible nipple shield rather than directly to a glass container.

Women have been using breast pumps to trigger the milk ejection response for centuries. The ancient Greeks used *guttus*—ceramic vessels with long necks and spouts—to both empty the breast and feed the infant a few drops at a time. The Romans used glass milk extractors, which were sucked by the mother herself. The first published evidence of the use of a glass implement for evacuating breast milk appears in a pediatrics textbook published in 1577 by Omnibonus Ferrarius. An illustration in the text shows a small, globular glass container widened at the lip and attached to a glass pipe at its base. The lip was placed over a woman's nipple, and the tip of the pipe was placed in her mouth. As she drew on the pipe, air was pulled from the apparatus, and the resulting suction triggered the expression of milk, which collected in the glass reservoir. Also called a sucking glass, the contraption was recommended as a method for reducing engorgement when a breast was not completely emptied. This model did not change much until the mid-19th century.

Needham's pump was the first of several improved devices that resemble modern human breast pumps. Recognizing that placing glass directly over the nipple could be painful, his model proposed the use of a nipple shield composed of India rubber that could fit snugly over the breast when suction was employed using a bellows. Needham's pump was designed to be hand operated, whereby a mother squeezed the bellows in a repetitive fashion, allowing her to control the pressure and frequency of milk expression. Small manual pumps proved inefficient, however, requiring significant effort on the part of the user and allowing for only one breast to be pumped at a time. These devices also failed to remove all of the milk from the breast.

The next important innovation came in the form of machine-driven suction. In the early 1920s, Edward Lasker created a mechanical breast pump that provided

intermittent sucking action imitating that of an infant. The pump was designed to create a massaging effect that would stimulate milk production. It was not until 1991 that Medela, a Swiss company, introduced the first nonhospital, electric-powered, vacuum-operated breast pump in the United States. Today's pumps allow women to extract their milk rapidly using a double pump, and to continue to express their milk for weeks or even months.

Kathleen Barker

See also *Vol. 2, Sec. 1: Curling Iron; Vol. 2, Sec. 2: Blender*

Further Reading

Williams, Florence. 2012. *Breasts: A Natural and Unnatural History*. New York: W. W. Norton and Company.

Yalom, Marilyn. 1997. *History of the Breast*. New York: Knopf.

Brown Truss

Invented by Josiah Brown Jr., the box truss became known more colloquially as a Brown truss. It was most often used in covered bridges and protected from the elements with outside sheathing. The Brown truss was designed with two-force members assembled such that the separate pieces work together as a single object. In this way, force is applied to only two points, making the structure more sound and capable of supporting more weight.

Brown described the way his truss would work in his 1857 patent application when he wrote, "when the timbers of the chords are brought together they are combined and become, as it were, only one piece, no part of which can be operated upon or affected independently of the other by the downward and upward thrusts common to truss bridges."

Further, by arranging stiff panels in a cylindrical shape, the Brown truss had a higher resistance to twisting along its long axis and a higher resistance to buckling than a simple truss. Many types of trusses existed and had been in service before Brown's invention, including the geodesic dome, a truss in the shape of a sphere.

Rosanne Welch

See also Howe Truss; *Vol. 1, Sec. 2*: Burr Truss Bridge

Further Reading

Hibbeler, Russell Charles. 1983. *Engineering Mechanics-Statics*. 3rd ed. New York: Macmillan.

Burglar Alarm

The first electromagnetic burglar alarm was invented by the Unitarian pastor Augustus Russell Pope (1819–1858) of Somerville, Massachusetts.

A Harvard graduate, Pope was an eloquent lecturer and a man of many interests, among them physics and mechanics, and the patent for his invention was granted on June 21, 1853 (U.S. Patent 9,802). Pope's design used a battery, magnets, and a bell as individual units mounted on each window or door. While a door is closed (or a window sash is down), the magnetic circuit is broken because the spring of the key is thrown out of connection with the upper wire of the door (or window frame), but as soon as the door or window is opened, the spring of the key comes into contact with the wire, closing the circuit. The electrical current flows through the circuit breaker, charging the magnet and drawing the hammer toward the bell, causing the bell to ring.

Pope installed the alarm in his own home and several other houses. He attempted to market his invention in the local newspapers, but the public was reluctant to embrace it. He even presented his invention at the Fair of the Mechanics Charitable Association in Boston in 1856, but it did not draw prospective customers and was never put into mass production, because the general public still mistrusted electricity and associated it with danger and even death.

In 1858, Pope sold and transferred the rights to his invention for \$8,000 in notes and \$1,500 in cash to Edwin Holmes of Boston, an entrepreneurial shopkeeper turned businessman who set up a company to install and operate electric burglar alarm systems in that city. Business took off a year later, after the Holmes Burglar Alarm Company moved to New York (where, so the company slogan said, "all the country's burglars made their home"). New York proved ideal for the business because the city had electrified and the public began warming up to the idea of electrically powered devices. Holmes proactively publicized his

product and made some improvements himself, which increased its popularity. By 1866, the number of his customers had reached 1,200.

Holmes's son, Edwin Thomas Holmes, also played an active role in the company and was in charge of operations in Boston, where the company had 700 customers. In Boston, Edwin decided to use preexisting phone cables instead of laying new ones dedicated for alarm use only. Other improvements included the use of one centralized bell (usually in the owner's bedroom) instead of separate bells on every door and window, the use of a clock to turn the alarm on and off, the introduction of zones, and building a network of alarms to be monitored by a central office. In 1905, the American Telephone and Telegraph Company purchased the Holmes Electric Protective Company and linked it to the police-and-firefighting emergency call system: the burglar alarm industry was born.

Stefka Tzanova

See also Telegraph; *Vol. 2, Sec. 1*: Electricity, War of Currents

Further Reading

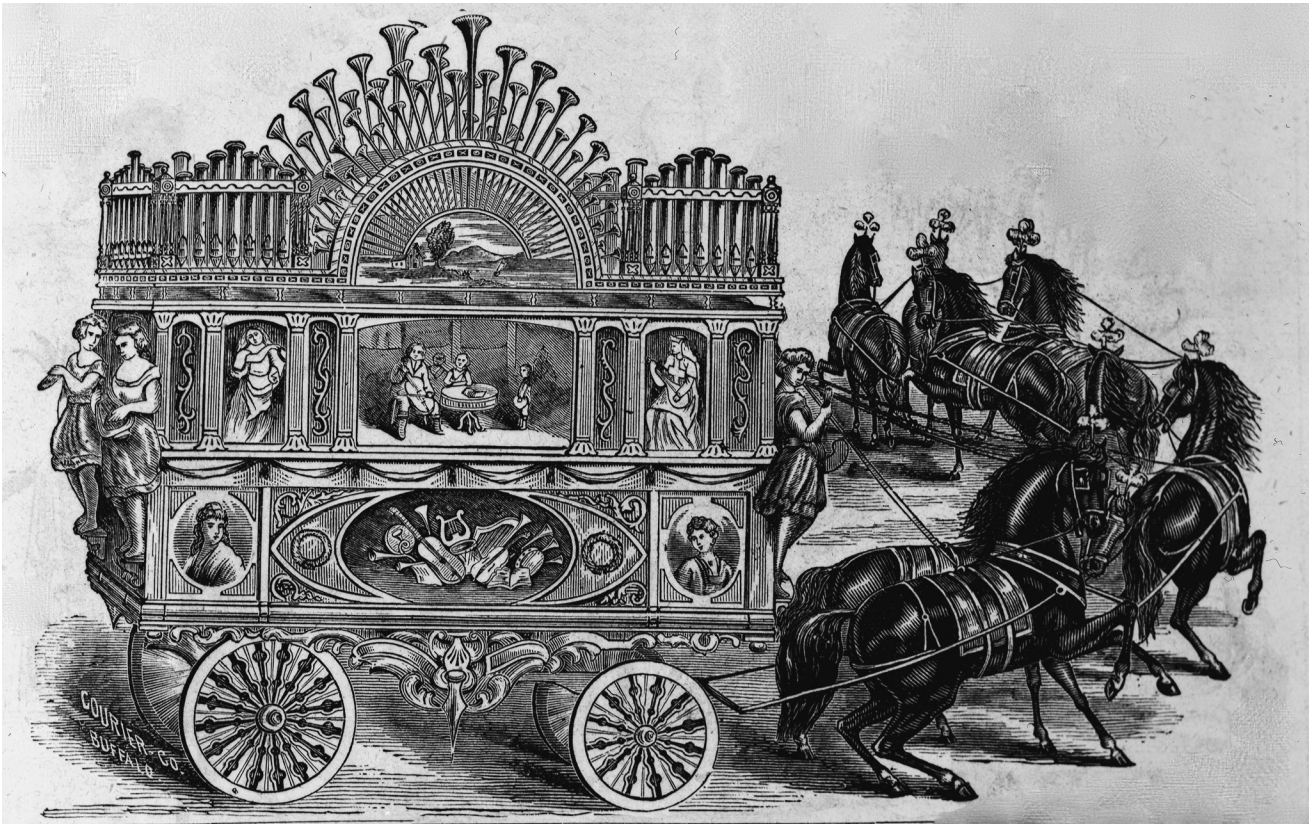
Holmes, E. T. 1917. *A Wonderful Fifty Years*. New York: Watkins Press.

Smith S., J. Ellis, and R. Abrams. 2010. "History of Central Alarm and Dispatch System." In *The Professional Protection Officer: Practical Security Strategies and Emerging Trends*. New York: Elsevier/Butterworth-Heinemann.

Calliope (Steam Organ)

The steam calliope, also known as the steam organ or steam piano, was patented by Joshua C. Stoddard in 1855. Originally designed as a replacement for church bells, the steam calliope became a popular attraction at circuses and on riverboats in the 19th century.

The calliope consists of a series of tuned steam trumpets or whistles that produce musical notes when steam is sent through them. Stoddard's original calliope consisted of 15 whistles that were attached to a small steam boiler and utilized roller-and-pin technology that was common in music boxes of the day. A revolving spoked cylinder opened and closed valves



Invented by Joshua Stoddard, a beekeeper from Massachusetts, the Calliope steam organ worked by forcing steam through a group of large whistles. The piano-player technology of the early 20th century replaced the calliope's human operator with a music roll. (Bettmann/Getty Images)

that controlled the flow of steam. Stoddard later replaced the cylinder with a keyboard so that the instrument could be played like a piano. The whistles were tuned to a chromatic scale, but it was difficult to keep a calliope in tune due to the fluctuating temperature of the steam. Early whistles were made of cast brass and often produced harsh and off-pitch notes. Beginning in 1890, the calliope manufacturer Thomas J. Nichol used sheet copper for the bells of the whistles to produce a "sweeter" sound.

The steam calliope with a keyboard debuted July 4, 1855, in Worcester, Massachusetts. Stoddard controlled the steam while his daughter played "Yankee Doodle." He patented this calliope that year and founded the American Steam Piano Company. Spaulding and Rogers Circus first introduced the calliope to their circus showboat, *The Floating Palace*. Steamboats supplied the required steam from their boilers, and calliopes were also installed in steam-driven carousels. In 1870, P. T. Barnum was so

impressed with the calliope that he had one installed in a circus wagon in hopes that it would draw crowds to his circus. It is said that Barnum renamed the steam organ "the calliope" after the Greek goddess of that name (which means "beautiful voice"). Although closely associated with circuses and circus wagons, calliopes were commonplace on steamboats after the Civil War.

Around 1900, manufacturers began to produce calliopes that used music rolls, much like a player piano. But the keyboard remained, allowing someone to play the instrument manually. It was during this time that compressed air began to replace steam in the instrument, making it safer and more convenient. The Tangley Calliaphone, a 43-whistle calliope, used compressed air and could play type A piano rolls. These popular calliopes could be played automatically or manually and were small enough to be mounted on wagons or automobiles. They were used as advertising gimmicks in the early 20th century.

Calliopes have between 25 and 67 whistles, with most having 32. The largest steam calliope ever built was for the *Mississippi Queen*, built in 1975. The *Mississippi Queen* calliope has 44 gold-plated, solid brass pipes. In 1958, Richard Simonton and E. J. Quimby purchased a calliope that had been salvaged from the *Water Queen*. They electrified the keyboard and replaced each steam valve with a solenoid valve. In 1960, they installed the converted calliope on the *Delta Queen*. It was the first calliope with a remote keyboard. It allowed the calliopist to play the instrument away from the whistles themselves. In the 1970s, several new steamboats were being built and needed steam calliopes. Dave Morecraft restored and then replicated a Nichol circus calliope. His first calliope is privately owned, and the second was installed on the *Belle of Louisville*. In 1975, an exact replica of a hundred-year-old calliope was built for the steamboat the *Natchez*.

Joshua C. Stoddard received little compensation for his invention. His parents did not approve of his frivolous instrument, and the city of Worcester banned the calliope within the city limits because of the noise. One of his financial backers, Henry Deny, eventually ousted Stoddard from the American Steam Piano Company and took over as its president. Deny later claimed that he had invented the calliope. After he lost control of his company, Stoddard returned to farming and beekeeping. Although he patented several other inventions, none were successes.

Kathleen Simonton

See also Vol. 1, Sec. 2: Fulton, Robert; Steam Engine; Steamboat

Further Reading

Espenshied, Steven. 1986. *The History of the American Steam Calliope*. Burlington, VT: Vantage Press.

Roehl, Harvey. 1961. *Player Piano Treasury*. New York: Vestal Press.

Cannon, Double-Barrel

The double-barrel cannon was an American Civil War-era experimental weapon that never saw battle. The

concept of the double-barrel cannon was created in 1862 by dentist, builder, and mechanic John Gilleland, who raised money via a subscription fund from Confederate citizens in Athens, Georgia, to build the ultimate chain-shot gun for \$350. Now the double-barrel cannon is one of the most popular landmark attractions in that city.

The double-barrel cannon featured side-by-side bores (barrels). The concept meant that artillerymen would load two cannonballs, linked together by a 10-foot chain, into each barrel. The cannon would then be fired using one vent hole to light the fuse, with the fuse leading to both tracks of the cannon. However, this ambitious idea had a timing issue that caused one barrel to fire sooner than the other. The chain often snapped, causing the two cannonballs to go in different directions. During testing, the “Secret Weapon” effectively mowed down trees, tore up a cornfield, knocked down a chimney and killed an unfortunate cow. Eyewitness accounts described the test firing as catastrophic; the fired cannonballs took a circular motion, plowing up about an acre of ground, tearing up corn and mowing down saplings. The weapon never hit its designated target during testing. Yet its unfortunate results did not deter Gilleland from declaring the testing an unqualified success.

The cannon was then sent to the Confederate arsenal in Augusta, Georgia, for further testing. The commandant there, Col. George W. Rains, tested the weapon extensively and reported that it was not usable due to unpredictable rates of powder burn and barrel friction that led to unreliable performance. The cannon was then sent back to Athens, Georgia.

This enraged Gilleland, who wrote many stern letters corresponding with the Confederate secretary of war, James W. Camak, to the Confederate government in Richmond, Virginia. Despite Gilleland’s displeasure, the Confederate government never used the double-barrel cannon in battle.

The cannon was placed in front of the Athens town hall, to be used as a signal gun in case of attack by the United States Army. It remained there until August 2, 1864, when it was hauled out of town to the hills by Barber Creek to repel the approach of Brig. Gen. George Stoneman and his Union cavalry troops. Reports say that the cannon was loaded with canister shots, not balls.

After the war, this bold weapon was placed at the corner of College and Hancock Avenues in Athens, Georgia, where it remains today.

Elijah Sisson

See also Columbiad Cannon; Dahlgren Gun

Further Reading

Hazlett, James C., M. Hume Parks, and Edwin Olmstead. 2004. *Field Artillery Weapons of the Civil War*. Urbana: University of Illinois Press.

Primary Document: Excerpt from the Memoirs of Former Confederate General Edward Porter Alexander on “Artillery Hell” at Antietam (1907)

Artillery was an important aspect of almost all Civil War battlefields. In the postwar years, the Battle of Antietam (also known as the Battle of Sharpsburg), fought in western Maryland on September 17, 1862, became particularly known for the devastating use of artillery on both sides. General Stephen D. Lee, a Confederate artilleryman, in a comment later recorded by General E. P. Alexander in the following passage from his 1907 memoirs, later remembered Antietam as “artillery hell.”

A strong feature of our centre was that the Antietam cut in half the ground over which the enemy must manoeuvre, and would more or less embarrass any infantry attack upon it; but, per contra, there were two ugly features: (1) The country is a rolling one and the hills near the stream are often quite steep, thus giving the enemy fairly close approach under cover. (2) Our whole line except the cavalry on the left was within range of the enemy’s rifle-guns planted along the high ridges east of the Antietam, beyond the effective range of our guns.

Thence, perfectly safe themselves, they practised upon us at leisure all day. Hunt, the Federal chief of artillery, describes the location of 10 heavy batteries of the reserve artillery, and says:—

They overlooked the enemy and swept most of the ground between them and our troops. They were well served, especially the guns of Benjamin’s battery. Their field of fire was extensive, and they were usefully employed all day and so constantly that the supply of ammunition for the 20-pounders ran short.

As to how our artillery fared in opposition, we may judge from a remark made to me two months later by Col. S. D. Lee, upon my being transferred to the artillery service: “Pray that you may never see another Sharpsburg. Sharpsburg was Artillery Hell.”

Source: Alexander, E. P. 1907. *Military Memoirs of a Confederate: A Critical Narrative*. New York: Charles Scribner’s Sons, 246–47.

Civil War Medicine (1861–1865)

The Civil War is considered the United States’ first modern war. It was the first to take place after the Industrial Revolution, which had made the large-scale manufacturing of armaments and the use of modern transportation, such as railroads, possible.

While the impact of such large-scale wars on the populations involved is obvious, what is often not widely noted are the rapid advances made by medicine during such times, and the Civil War was the first American war to have its medical care thoroughly documented. While the improvements of that time may seem primitive by today’s standards, they set the

stage for a rapid advance of the overall quality of American medical practice.

As a result of what was learned in the war, the training of thousands of physicians was upgraded, and they were introduced to improved standards of care. These included advances in techniques for the prevention and treatment of infectious disease, improvement in surgical principles, and more rapid and systematic assessment of patients’ needs.

The Civil War resulted in the highest number of deaths of all the wars in which Americans have fought. A total of 620,000 men died: 360,000 in the North and 260,000 in the South, which was about a quarter of all who served. However, most of these men died from

illness, not injury. For every three soldiers killed in battle, five more died of disease. Typhoid fever was a leading killer, and diarrhea affected 74 percent of soldiers in any given year.

Those who were injured in battle faced their own unique set of problems. Medical care for the casualties from the first Battle of Bull Run in July 1861 was essentially nonexistent. There was no organized evacuation of these men, and no hospitals were available to handle their numbers. Those wounded who could evacuate themselves filled the streets of Washington, D.C., seeking shelter and treatment. Those who could not lay unattended on the battlefield, where they died of their injuries, thirst, or exposure.

The Union Army would come to rely on one very important ally whose focus was dedicated to the improvement of care—the United States Sanitary Commission (USSC).

At the start of the war in April 1861, there was an outpouring of support and concern by the public for the troops' welfare. A delegation of New York City's civic leaders and medical community went to Washington, D.C. to appeal to the federal government to form an aid group. The USSC was created by federal legislation on June 18, 1861, with its initial mission to support sick and wounded soldiers who had volunteered to fight (at the outbreak of the war, the regular U.S. Army consisted of only 16,200 men, far below the number that would be needed in the conflict). Later it would expand its service to regular army troops and sailors. Operating across the North, the USSC raised nearly \$25 million over the course of the war to support the cause, and enlisted thousands of aid volunteers.

Pressure from members of the USSC was responsible for the appointment of Surgeon General William Hammond in April 1862. He appointed an army medical director, Jonathan Letterman, who would become known as “the father of modern battlefield medicine.” These men initiated a series of reforms that would vastly improve the handling of the sick and wounded.

Hammond required medical officers to submit reports of their activities, treatments used, and their results. After the war, these records were collected into a six-volume set, the *Medical and Surgical History of the War of the Rebellion*, which was the first major American academic medical contribution

recognized in Europe. It provided detailed written and visual documentation of medical and surgical management during the war. These records allowed medical personnel to compare treatment approaches.

Another issue Hammond took up in 1862 was the lack of competence of army medical officers. Even those designated as surgeons frequently had little or no operative training, and a complete lack of knowledge regarding sanitation was common. Hammond developed a medical examination process to weed out those with inadequate training. He also developed a hospital inspection system to ensure adequate levels of cleanliness and care.

An intense hospital building program was started in 1862. By the end of the war, these hospitals were built in a pavilion style, which consisted of long, separate ward buildings with high, arched ceilings that allowed for greater ventilation. Patients with similar ailments were housed together. During the Crimean War, British nurse Florence Nightingale had demonstrated that this style of hospital, when combined with cleanliness, helped prevent the spread of illness. This design would be copied for large civilian hospitals for the following 75 years.

Nursing care was another issue. Initially, men from the ranks performed nursing chores. These were either sick soldiers who had recovered sufficiently to do the job, or those who had been sent from their regiments to work in the hospitals (the latter were often poor performers who had been dispatched simply to get rid of them). Women had served as nurses in a limited capacity during the Crimean War, but the Civil War would mark their first widespread use. Dorothea Dix, a teacher and advocate for the mentally ill, volunteered to put together a corps of female nurses. The women serving in Union hospitals would grow to 3,000 or 4,000 in number by the end of the war.

While Hammond worked on raising standards, Letterman devised a system of managing mass casualties, starting with aid stations set up immediately behind the scene of battle. Treatment at the aid stations consisted of controlling bleeding, bandaging wounds, and administering morphine and whiskey for pain. It was learned there that bleeding was best controlled by pressure dressings or by using stitches. The use of stitches and the associated skill developed in

applying them was one of the major advances in surgical technique of the time.

The next link in Letterman's system was the field hospital. From an aid station, soldiers could be taken via horse-drawn ambulances to these hospitals, which were within a mile or two of the battlefield.

Medical personnel learned that any definitive treatment of wounds should take place within 24 hours of the injury. The existence of bacteria and viruses and their role as causes of infection was not yet known, but it was recognized that when wounds were treated quickly, the patient was more likely to recover. It was at field hospitals that most surgeries took place.

The vast majority of battlefield wounds were caused by bullets, with the arms and legs most frequently affected, leading to amputation being the most common surgical procedure. While the mortality rate was high—about 25 percent of amputation patients died—the rapid treatment combined with the operative experience gained by surgeons meant that the death rate was much lower than for the same surgery in the civilian world: around 75 percent.

Anyone who required longer-term care could be sent to a general hospital in or near a major northern city. The availability of these general hospitals meant that field hospitals could be emptied rapidly if necessary, leaving them prepared for the next battle. This system would provide the basis for managing the wounded, from World War I until the Korean War.

It was in the general hospitals that wound infections such as gangrene were treated. Middleton Goldsmith, surgeon in chief of the military hospitals in Kentucky and Ohio, noted that patients whose rooms were deodorized with a spray containing bromine, an antiseptic related to chlorine, seemed to recover from gangrene more frequently. He developed a gangrene treatment in which the affected area was cleansed directly with a bromine solution. As a result, deaths

from gangrene fell from 60 percent to just 2.6 percent.

Another surgeon, William W. Keen, stopped a gangrene epidemic at his hospital in Philadelphia by isolating the affected patients, using fresh bandages on all wounds, dressing infected wounds last, and requiring cleanliness of all personnel, including that they had to wash hands between cases. This inspired an entirely new standard of care.

Advances were also made in reconstructive surgery. Eleven percent of battle wounds were to the face and neck and, as the war progressed, devastating injuries to the face were treated successfully, usually by stretching a flap of adjacent unaffected skin over the wound in a technique similar to what was done to cover the end of an amputated limb. After the war, additional surgeries to improve function and appearance were often conducted and the results recorded, providing a base for the development of modern plastic surgery.

As a result of what was learned because of the war, the general populace benefited from better-trained medical personnel, who were beginning to understand the value of sanitation and the importance of prompt treatment in better outcomes for their patients.

Nancy Beach

See also Civil War Nursing

Further Reading

Blaisdell, F. W. 1988. "Medical Advances during the Civil War." *Archives of Surgery* 123: 1045–50.

Civil War Trust. <http://www.civilwar.org/>, accessed August 22, 2018.

United States Sanitary Commission. 1861–1879. "United States Sanitary Commission Records." The New York Public Library Archives and Manuscripts. <http://archives.nypl.org/mss/3101>, accessed August 22, 2018.

Primary Document: Report of Medical Director Robert Murray on Union Casualties Suffered at the Battle of Shiloh (1862)

In April 1862, Robert Murray was medical director for the military district Department of the Ohio and traveled to the Battle of Shiloh (April 6–7) with the

Army of the Ohio commanded by General Don Carlos Buell. At Shiloh, Buell's army reinforced General Ulysses S. Grant's Army of the Tennessee, which was

there heavily engaged with the Confederates. As the ranking medical officer on the field, Murray issued the following report on Union casualties at Shiloh on April 21, 1862. Shiloh, also known as the Battle of Pittsburgh Landing, was the deadliest battle of the Civil War up to that time, with almost 24,000 casualties between the two sides.

MEDICAL DIRECTOR'S OFFICE, ARMY OF THE OHIO,

Camp on Field of Shiloh, April 21, 1862.

SIR: I have the honor to submit the following report of the operations of the medical department during and after the battle of the 6th and 7th instant:

On the morning of the 6th I was at Savannah, and being ordered to remain at that place, I occupied myself in procuring all the hospital accommodation possible in that small village and in directing the preparation of bunks and other conveniences for wounded. In the afternoon the wounded were brought down in large numbers, and I then superintended their removal to hospitals, and did all in my power to provide for their comfort. On Sunday evening, the divisions being under orders to come up as rapidly as possible, I ordered the medical officers, as it was impossible to take their medical and hospital supplies—the teams and ambulances being in the rear and the roads blocked up with trains—to take their instruments and hospital knapsacks and such dressings and stimulants as could be carried on horseback, and to go on with their regiments. I left Savannah by the first boat on Monday, and arrived at Pittsburg Landing at about 10 a.m. I found the principal depot for wounded established at the small log building now used as a field post-office. They were coming in very rapidly, and very inadequate arrangements had been made for their reception. I found Brigade Surgeon Goldsmith endeavoring to make provision for them, and at his suggestion immediately saw General Grant, and obtained his order for a number of tents to be pitched about the log house.

I then rode to the front and reported to you. The great number of wounded which I saw being transported to the main depot, and the Almost insurmountable difficulties which I foresaw would exist in providing for them, convinced me that my presence was needed there more than at any other point on

the field. After spending an hour in riding a little to the rear of our lines, and seeing as far as possible that there were surgeons in position to attend immediately to the most urgent cases, I returned to the hill above the Landing, and used every exertion to provide for the wounded there. I ordered Brigade Surgeons Gross, Goldsmith, Johnson, and Gay to take charge of the different depots which were established in tents on the hills above the Landing, directing such regimental and contract surgeons as I could find to aid them. Many of the wounded were taken on board boats at the Landing and some of our surgeons were ordered on board to attend them. On Tuesday I had such boats as I could obtain possession of fitted up with such bed-sacks as were on hand and with straw and hay for the wounded to lie upon, and filled to their utmost capacity, and at once dispatched to convey the worst cases to the hospitals on the Ohio River, at Evansville, New Albany, Louisville, and Cincinnati. In removing the wounded we were aided by boats fitted up by sanitary commissions and soldiers' relief societies and sent to the battle-field to convey wounded to the hospitals. Some of these, especially those under the direction of the United States Sanitary Commission, were of great service. They were ready to receive all sick and wounded, without regard to States or even to politics, taking the wounded Confederates as willingly as our own. Others, especially those who came under the orders of Governors of States, were of little assistance, and caused much irregularity. Messages were sent to the regiments that a boat was at the Landing ready to take to their homes all wounded and sick from certain States. The men would crowd in numbers to the Landing, a few wounded, but mostly the sick and homesick. After the men had been enticed to the river and were lying in the mud in front of the boats it was determined in one instance by the Governor to take only the wounded, and this boat went off with a few wounded, leaving many very sick men to get back to their camps as they best could. By the end of the week after the battle all our wounded had been sent off, with but few exceptions of men who had been taken to camps of regiments in General Grant's army during the battle. These have since been found and provided for.

The division medical directors were very efficient in the discharge of their duties, and they report most

favorably of the energy and zeal displayed by the medical officers under them in the care of the wounded under most trying circumstances—of want of medical and hospital stores, and even tents. Owing to the fact that a large majority of the wounded brought in on Monday and Tuesday were from General Grant's army, some of whom had been wounded the day before, it was impossible to attend particularly to those from our own divisions. Many Confederate wounded also fell in our hands, and I am happy to say that our officers and men attended with equal assiduity to all. Indeed, our soldiers were more ready to wait on the wounded of the enemy than our own. I regret to say that they showed incredible apathy and repugnance to nursing or attending to the wants of their wounded comrades, but in the case of the Confederates this seemed in some measure overcome by a feeling of curiosity and a wish to be near them and converse with them.

We were poorly supplied with dressings and comforts for the wounded and with ambulances for their transportation, and it was several days after the battle before all could be brought in. Our principal difficulty, however, in providing for the wounded was in the utter impossibility to obtain proper details of men to nurse them and to cook and attend generally to their wants, and in the impossibility of getting a sufficient number of tents pitched, or in the confusion which prevailed during and after the battle to get hay

or straw as bedding for the wounded or to have it transported to the tents. The only details we could obtain were from the disorganized mob which lined the hills near the Landing, and who were utterly inert and inefficient. From the sad experience of this battle and the recollections of the sufferings of thousands of poor wounded soldiers crowded into tents on the wet ground, their wants partially attended to by an unwilling and forced detail of panic-stricken deserters from the battle-field, I am confirmed in the belief of the absolute necessity for a class of hospital attendants, enlisted as such, whose duties are distinct and exclusive as nurses and attendants for the sick, and also of a corps of medical purveyors, to act not only in supplying medicines, but as quartermasters for the medical department.

I append a list of the number of killed and wounded in each regiment, brigade, and division engaged, in all amounting to 236 killed and 1,728 wounded.

Very respectfully, your obedient servant,
R. MURRAY,
Surgeon, U. S. Army, Medical Director.
Col. J. B. FRY,
Asst. Adjt. Gen. and Chief of Staff, Army of Ohio.

Source: *The War of the Rebellion: A Compilation of the Official Records of the Union and Confederate Armies*. Series I, Volume X. Part I: Reports. Washington, D.C.: Government Printing Office, 1884, 296–99.

Civil War Nursing

Motivated by patriotism, compassion, economic necessity, or obligation, both black and white women nursed sick and injured soldiers on both sides of the conflict during the American Civil War. Female nurses confronted class and gender biases by taking on hospital work, paving the way for nursing to become an acceptable profession for middle-class women in the late 19th century. The vast majority of nurses did not continue their hospital work after the war, but a few prominent women continued to administer hospitals, train nurses, and receive medical training.

Hannah Ropes (1809–1863), an abolitionist who worked at Union Hospital in Washington, D.C.,

explained her motivations to care for soldiers: “I am a mother, and I have only to remember that each of these sick ones [has] a mother somewhere, and for the time I act for them” (Brumgardt 1980, 89). Female nurses acted as surrogate mothers and sisters, reminding sick and wounded soldiers of home. While Americans associated comfort, feeding, and caring for the sick with appropriate women's roles, nursing strange men in a hospital challenged middle-class notions of respectability.

Union and Confederate records are incomplete, and calculations vary based on one's definition of “nurse,” but using a congressional study of hospital attendants compiled in 1890, Jane E. Schultz asserts that over 21,000 women nursed Union soldiers during

the war. Regardless of job title (cook, matron, or nurse), nearly all women attendants were involved in some aspect of patient care, delivering food, cleansing wounds, or changing linens. Even regimental laundresses often doubled as nurses, caring for sick soldiers or assisting the wounded on the battlefield. Fewer white women worked in Confederate hospitals, as the system relied heavily on slave labor. Using the appropriations for the Confederate Medical Department, Libra R. Hilde (2012) estimates that 1,666 women worked as hospital matrons in 1864, and in 1863, nearly half of the attendants in Georgia's 19 hospitals were enslaved. A few women, such as Clara Barton, tended soldiers on the battlefield, but most women nurses worked in urban areas far away from the fighting. Not all women accepted pay for their services, so actual numbers could be higher than these estimates.

The Confederate Army and the Union Army structured hospital work according to race and class. In 1861, U.S. secretary of war Simon Cameron appointed Dorothea L. Dix as superintendent of army nurses. An experienced activist for the mentally ill, Dix sought to manage the flood of volunteers who sought nursing positions. To avoid sexual innuendo and potential romantic attachments, Dix only approved applicants who were over age 30, were plain looking, and had certified recommendations from physicians and clergymen. Dix's requirements reflected a preference for hiring mature, respectable white women in positions of authority, but aspiring nurses often maneuvered around Dix's restrictions. In October 1863, disgruntled surgeons also undercut her authority when General Order No. 351 permitted the surgeon general to appoint nurses without Dix's approval. Louisa May Alcott managed to gain a nursing position at the Union Hotel Hospital in Washington, D.C. Her story illustrates the danger of volunteering as a nurse in that she contracted typhoid after three weeks and nearly died. Her first book, *Hospital Sketches*, was a collection of letters from her nursing service.

Confederate hospital matrons also tended to be mature white women, widowed or unmarried, from the middle or upper classes. They managed a hospital's domestic operations by securing and distributing food and supplies, overseeing the kitchen and laundry, and supervising hospital workers except physicians. In

both Union and Confederate hospitals, ward nurses cleaned wounds, changed bandages, applied poultices, changed bedpans and linens, scrubbed floors, fed patients, wrote letters (if literate), and visited with patients. Ward nurses included middle- and working-class white women, convalescent soldiers, and Catholic sisters. Black men and women tended to be assigned the most menial or difficult tasks in the wards, laundries, and kitchens. The U.S. and Confederate governments recognized the value of women's labor by paying them for their services. Although pay arrangements varied, Dix's nurses earned 40 cents per day, and head matrons in Confederate hospitals earned \$40 per month.

Approximately 600 sisters from 21 different religious communities nursed both Union and Confederate troops in hospitals, prisons, and transport ships between 1861 and 1865 (Maher 1989, 38, 70). Mary Denis Maher argues that the structure and training of their religious communities made Catholic sisters good fits for service in military hospitals. Communities with nursing experience, such as the Daughters of Charity, had the skills and discipline to work effectively with doctors and patients, manage supplies, and maintain the cleanliness of a hospital. Half of the sister-nurses who served during the war belonged to the Daughters of Charity, and 90 of them staffed Satterlee Hospital in Philadelphia, the largest Union hospital, which housed 7,000 patients after the Battle of Gettysburg. While sisters confronted anti-Catholic prejudices during the war, physicians generally appreciated their services. Reactions from other women nurses remained mixed. Some nurses and relief workers praised the sisters' efforts, but conflicts could emerge partly because the sisters insisted on maintaining a hospital environment where they could follow their religious community's rules and established procedures.

By working in a military hospital, women nurses from all backgrounds and income levels challenged 19th-century domestic ideology, which asserted that the proper place for middle-class women was in the home. While patients often appreciated their comforting presence, many physicians resisted women's involvement in hospital work. Convalescent soldiers understood their place in the military hierarchy, but middle- and upper-class nurses expected to be treated

as equals and often publicly criticized doctors' and surgeons' shortcomings.

Kristine Ashton Gunnell

See also Dix, Dorothea; U.S. Sanitary Commission (USSC)

Further Reading

Brumgardt, John, ed. 1980. *Civil War Nurse: The Diary and Letters of Hannah Ropes*. Knoxville: University of Tennessee Press.

Hilde, Libra R. 2012. *Worth a Dozen Men: Women and Nursing in the Civil War South*. Charlottesville: University of Virginia Press.

Maher, Mary Denis. 1989. *To Bind Up the Wounds: Catholic Sister Nurses in the U.S. Civil War*. Westport, CT: Greenwood.

Schultz, Jane E. 2004. *Women at the Front: Hospital Workers in Civil War America*. Chapel Hill: University of North Carolina Press.

Primary Document: Clara Barton's Poem "The Women Who Went to the Field" (1892)

In November 1892, Clara Barton read the following poem about Civil War nurses during a reception held at the Willard Hotel in Washington, D.C., for the Potomac Relief Corps, a unit of the National Woman's Relief Corps. Barton volunteered as a nurse during the Civil War, distributing supplies, cleaning hospitals, and nursing wounded and sick soldiers. Her nursing work during the war earned her the nickname "Angel of the Battlefield."

The Women Who Went to the Field
The women who went to the field, you say,
The women who went to the field; and pray,
What did they go for?—just to be in the way?—
They'd not know the difference betwixt work
and play,
What did they know about war, anyway?
What could they do?—of what use could they
be?
They would scream at the sight of a gun, don't
you see?
Just fancy them round where the bugle notes
play,
And the long roll is bidding us on to the fray.
Imagine their skirts 'mong artillery wheels,
And watch for their flutter as they flee 'cross
the fields
When the charge is rammed home and the fire
belches hot;—
They never will wait for the answering shot.
They would faint at the first drop of blood, in
their sight.
What fun for us boys,—(ere we enter the fight;)

They might pick some lint, and tear up some
sheets,
And make us some jellies, and send on their
sweets,
And knit some soft socks for Uncle Sam's
shoes,
And write us some letters, and tell us the
news.
And thus it was settled by common consent,
That husbands, or brothers, or whoever
went,
That the place for the women was in their own
homes,
There to patiently wait until victory comes.
But later, it chanced, just how no one knew,
That the lines slipped a bit, and some 'gan to
crowd through;
And they went,—where did they go?—Ah;
where did they not?
Show us the battle,—the field,—or the spot
Where the groans of the wounded rang out on
the air
That her ear caught it not, and her hand was
not there,
Who wiped the death sweat from the cold,
clammy brow,
And sent home the message;—"T is well with
him now"?
Who watched in the tents, whilst the fever
fires burned,
And the pain-tossing limbs in agony turned,
And wet the parched tongue, calmed deliri-
um's strife

Till the dying lips murmured, "My Mother,"
 "My Wife"!
 And who were they all?—They were many, my
 men:
 Their record was kept by no tabular pen:
 They exist in traditions from father to son.
 Who recalls, in dim memory, now here and
 there one.—
 A few names where writ, and by chance live
 to-day;
 But's a perishing record fast fading away.
 Of those we recall, there are scarcely a score,
 Dix, Dame, Bickerdyke,—Edson, Harvey and
 Moore,
 Fales, Wittenmeyer, Gilson, Safford and Lee,
 And poor Cutter dead in the sands of the sea;
 And Frances D. Gage, our "Aunt Fanny" of
 old,
 Whose voice rang for freedom when freedom
 was sold.
 And Husband, and Etheridge, and Harlan and
 Case,
 Livermore, Alcott, Hancock and Chase,
 And Turner, and Hawley, and Potter and Hall,
 Ah! the list grows apace, as they come at the
 call:
 Did these women quail at the sight of a gun?
 Will some soldier tell us of one he saw run?
 Will he glance at the boats on the great west-
 ern flood,
 At Pittsburg and Shiloh, did they faint at the
 blood?
 And the brave wife of Grant stood there with
 them then,
 And her calm, stately presence gave strength
 to his men.
 And Marie of Logan; she went with them too;
 A bride, scarcely more than a sweetheart, 't is
 true.
 Her young cheek grows pale when the bold
 troopers ride.
 Where the "Black Eagle" soars, she is close at
 his side,
 She staunches his blood, cools the fever-burnt
 breath,
 And the wave of her hand stays the Angel of
 Death;

She nurses him back, and restores once again
 To both army and state the brave leader of
 men.
 She has smoothed his black plumes and laid
 them to sleep,
 Whilst the angels above them their high vigils
 keep:
 And she sits here alone, with the snow on her brow—
 Your cheers for her comrades! Three cheers for
 her now.
 And these were the women who went to the
 war:
 The women of question; what did they go for?
 Because in their hearts God had planted the
 seed
 Of pity for woe, and help for its need;
 They saw, in high purpose, a duty to do,
 And the armor of right broke the barriers
 through.
 Uninvited, unaided, unsanctioned oft times,
 With pass, or without it, they pressed on the
 lines;
 They pressed, they implored, till they ran the
 lines through,
 And this was the "running" the men saw them
 do.
 'T was a hampered work, its worth largely lost;
 'T was hindrance, and pain, and effort, and
 cost:
 But through these came knowledge,—knowledge
 is power.—
 And never again in the deadliest hour
 Of war or of peace shall we be so beset
 To accomplish the purpose our spirits have
 met.
 And what would they do if war came again?
 The scarlet cross floats where all was blank
 then.
 They would bind on their "brassards" and
 march to the fray,
 And the man liveth not who could say to them
 nay;
 They would stand with you now, as they stood
 with you then,
 The nurses, consolers, and saviours of men.

Source: Barton, Clara. 1898. *The Red Cross*. Washington, D.C.: American National Red Cross, 509–13.

Clipper Ship

The clipper ships of the 1840s portrayed a romantic image of plying the seven seas as the sleek ships' white canvas sails billowed in the wind as they cut across the ocean waves. These ships were beautiful to look at and designed for speed, but built for a very practical purpose.

The American colonies had won independence from Great Britain in 1783. The new country needed money, so trade was essential both within the United States and with other countries. American ships had to compete with those from countries that had long-established trade routes, and one way to do that was to be faster.

American schooners raided British vessels during the War of 1812. Schooners were small, agile, and maneuverable. They had two masts with lots of canvas sails to capture the wind. Larger, less maneuverable British ships could not catch them.

The United States defeated the British, and the war ended in 1815. Ships built during peacetime were designed to carry cargo. Flat-bottomed ships held more, but they were slower, sluggish in the water, and easily caught by the ships of other countries or boarded by pirates. Peace had been established on paper between the United States and Great Britain, and though neutral in conflicts between Great Britain and France, American ships were still boarded and had their cargo stolen. Again, the United States needed fast ships to compete.

U.S. trade with the West Indies and South America was for fruit and other food, coffee, and spices. Slow ships were raided and lost their cargo, or fresh cargo spoiled on too long a voyage home. Ships needed to get to their destinations quickly and return home quickly. American ships changed their design to increase speed while still allowing room for cargo. The front section, or bow, of the ship was sharpened, and the ship's bottom, or keel, was built less flat.

Another way for American ships to compete was to offer new services. Prior to 1818, ships had left port when they had enough cargo or passengers to make a profit and when the weather permitted. Starting in

January 1818, the Black Ball Line offered a departure schedule. These so-called "packet ships" sailed the first and 16th of the month in any weather, with full cargo and passengers or not. They carried mail packets and passengers from America to Britain and brought immigrants, cargo, and mail back. The trip from New York to Liverpool took about 23 days. The fastest time was 15 days.

The design of ships continued to develop as builders sought to make each ship faster than the last. The hull of the schooner curved more and evolved into a design for ships known as "Baltimore clippers." The term "clip" means to go fast. Instead of riding on top of the waves, clippers were described as cutting through the ocean like scissors.

Baltimore clippers were used for trade along the eastern United States and the Caribbean. They were built to be fast to carry spoilable cargo back to U.S. ports. They also sailed to Africa and brought slaves to plantations in Cuba and the United States.

One of the first Baltimore clippers was the schooner *Ann McKim*. The ship was built in Baltimore in 1832, weighed 494 tons, and was 143 feet long. It was the fastest merchant ship at the time. Its first voyages were to China. Later voyages to South America recorded its fastest sailing times of 51 days from Valparaiso, Chile, to San Francisco (1849) and 47 days from San Francisco to Valparaiso (1850).

The British East India Trading Company was established by British Parliament in 1600 to handle trade with Great Britain and her colonies. It controlled most of the ports in British-controlled parts of China and East India by the late 1700s. As a Parliament-sanctioned legal monopoly of these ports, its profits were huge. Many complained about the lack of free trade. The Company's power and influence only decreased when non-East India Trading Company ships were allowed to sail and trade in the Orient beginning in 1832.

Considered by some to be the first true clipper, the American ship *Rainbow* was built in 1845 for travel from New York to Canton. It weighed 750 tons and had three masts. Its first voyage to Hong Kong took 102 days. Its return voyage took 108 days.

Gold was discovered at Sutter's Mill, California, in 1848. The California Gold Rush was in full swing by 1849, and so was the demand for the fastest route to the West Coast. Miners wanted to get to San Francisco and nearby Sutter's Mill, and merchants wanted to get there to sell supplies and mining equipment.

The East India Trading Company's power eroded even more in 1849 when navigation laws were repealed. This opened Great Britain's and its colonies' ports to all ships.

Clippers were known for sailing day and night in good weather or bad. They were fast because they had sharp-lined hulls in proportion to their beam and carried lots of canvas. To reach these additional trade routes in India, China, and California they were redesigned again.

The *Stag Hound* was built in 1850 by prominent shipbuilder Donald McKay. The ship weighed 1,534 tons and carried 11,000 yards of canvas sail. The *Stag Hound* was called an extreme clipper because it was the longest and largest merchant ship at the time. On its best day, it sailed 358 miles.

The 1,800-ton *Flying Cloud* was built the following year. On its maiden voyage from New York to San Francisco via Cape Horn (the southernmost tip of South America), the ship completed the voyage in 89 days and 21 hours. The ship broke its own record in 1854, and that record of 89 days and 8 hours held until 1989.

The *Great Republic*, at over 4,500 tons, was the largest clipper ship ever built. It measured 335 by 53 by 38 feet. Completed in 1853, it was destroyed in dock by a wharf fire before its maiden voyage. The ship was rebuilt and had over 15,000 yards of canvas sail. A 15-horsepower engine raised its sails and moved cargo.

There were two water routes to get from the East Coast of the United States to the West Coast. One was by sailing south around Cape Horn and then north to San Francisco—over 13,000 nautical miles. The shorter route of 5,000 miles was by sailing south to Panama, crossing by land the fever- and disease-ridden Isthmus of Panama, and then going by ship again north to San Francisco.

Clipper ships ruled the oceans for about a decade. While the *Great Republic* was powered by wind in its sails but used an engine to move cargo, competition from ships powered not by wind but by steam engines started to grow. A few sailing ships had steam engines as backup power if there was no wind. Some ships used steam engines to maneuver in harbors. Steam-powered ships crossing the open ocean were just a matter of time.

Demand for clipper ships declined after the opening of the Suez Canal in 1869. The canal allowed ships from European ports to reach the Pacific Ocean and western United States much faster and safer than by the Cape Horn or Isthmus of Panama routes. Ships' design changed to have fewer sails, fewer sailors, more cargo, and more profit.

The *Ann McKim* was dismantled in Valparaíso, Chile, in 1852. The *Rainbow* left New York for China via Valparaíso and was never seen again. The *Stag Hound* burned off the coast of Brazil in 1863. The *Flying Cloud* was destroyed by fire in 1874 in Saint John, New Brunswick. The *Great Republic* foundered in a hurricane off Bermuda in 1872. These were just some of the clipper ships of the time.

Although the clipper ship era was short, it exemplified a time of innovation and experimentation. Competition for trade routes created competition between captains and crew to be the best: a fast ship could be built to be even faster.

Linda Briley-Webb

See also *Vol. 1, Sec. 1*: Schooner; *Vol. 1, Sec. 2*: Charting the Gulf Stream

Further Reading

- Clark, Arthur H. 1970. *The Clipper Ship Era*. Riverside, CT: The 7 C's Press.
- Cutler, Carl C. 1984. *Greyhounds of the Sea*. Annapolis, MD: Naval Institute Press.
- Howe, Octavius T., and Frederick C. Matthews. 1986. *American Clipper Ships 1833–1858*. Vols. 1 and 2. Mineola, NY: Dover.
- Villiers, Alan. 1973. *Men, Ships and the Sea*. Washington, D.C.: The National Geographic Society.

Primary Document: Excerpts from the Journal of Alexander Van Valen Describing His Journey to California via Clipper Ship (1849)

In 1849, Alexander Van Valen traveled from New York to California by clipper ship. Van Valen discovered that conditions aboard ship were significantly less pleasant than shipping advertisements had suggested, but he remained impressed with the speed of travel.

Wednesday Feb 14, 1849. 6 a.m. Cloudy. Weather mild, light winds and variable, we now begin to feel the inconvenience of a Small Ship crowded with Passengers, a Small Cabin crowded with Baggage & no Ventillation, and to make the place still more disagreeable especially in the warm Latitudes the Cabin is furnished with 3 or 4 dirty & half trimmed

Oil Lamps, which emits a Smoke equal to a Blast furnace. 12 m Lat 10° 25' North Long 25° 05' West. nothing worthy of note occurred the remainder of the day. I find it quite a task, especially one like myself who have allways been engaged in other pursuits than writing, to find material about which to write. there is much of a Sameness on Ship Board day after day, and seldom anything occurs to change the Monotony of the Scenes. Thursday Feby, 15, 1849 5 am. Arose this morning and took a Bath, which is performed in the following maner, some 4 or 5 club together, one of which takes a Bucket, draws the water and dashes it upon the rest & Visa Versa. Weather warm light wind from the North East. The Temperature of the weather about the same as July or

August in New York. 12 m, Lat 8° 01' North. Long 25° 05' West.

Wednesday May 23rd 1849. Weather Cool. Wind South blowing a good Stiff breese. we dropped Anchor in harbour opposite the City of Valparaiso about 12 M. making the Passage from St. Catherines to this place in 53 days and from New York including 14 days stoppage at St. Catherines in 121 days. Valparaiso lies in Lat 32° 51' South. Long 73° 57' West. We had a beautiful Sail along up the Coast this morning going at the rate of 10 to 12 Miles an hour under a full spread of Canvass. 6 other vessels going in at the same time, giving us a fair trial of our Barks Sailing qualities. And I must say she did her part nobly. if the chase had been of a few hours longer duration I think we would have beat the whole fleet. We had a fair opportunity of viewing the beautiful Mountain Scenery along the Coast, which for grandeur, magnificence and wildness, exceeded anything of the Kind it has been my lot to behold before. and farther back from the Coast range the lofty Andes, raising their bold Peaks and piercing the clouds with their Snow-capt Summits. Constrasting beautifully with the dark foliage of the Mountains below, the Harbour presented quite an imposing appearance. there were lying at anchor upwards of 50 vessels, of all classes.

Source: *Alexander Van Valen Diary, 1849–1850.* New York: Blank Book Manufacturers.

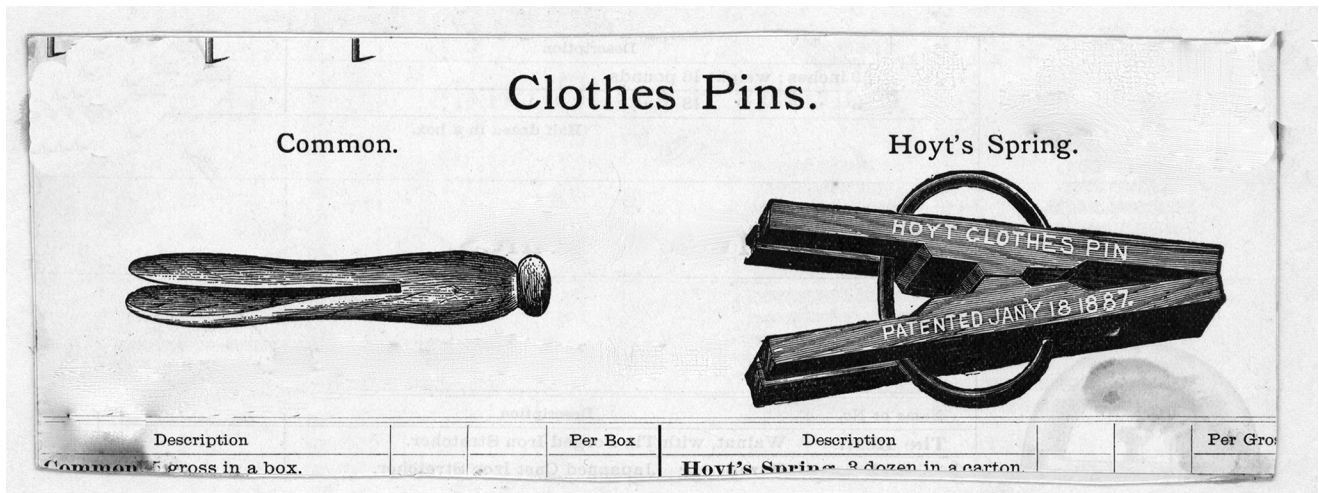
Clothespin

The clothespin is a fastener used to affix clothes to a clothesline. The clothespin is different from the clothes-peg, a two-pronged, single piece of wood, in that the clothespin is made up of two separate pegs with a central spring. “Mother” Ann Lee, leader of the Shakers, an American religious group, invented the clothes-peg in the 1700s. Clothes-pegs remain in use today, both for laundry and for decorative and crafting purposes. Romani people, commonly known as gypsies, also made clothes-pegs, generally from split pieces of willow.

David M. Smith patented the modern clothespin in 1853. Spring-loaded clothespins are considered sturdier than clothes-pegs and capable of holding heavier laundry loads. In the three decades that followed Smith’s 1853 patent, 146 different designs for clothespins were submitted to the U.S. Patent Office.

In the 21st century, clothespins are considerably less common than they used to be, in part because of the proliferation of electric or gas home dryers. A renaissance in line drying, brought on by environmental and energy conservation concerns, has led to a resurgence of the clothespin.

Peg A. Lamphier



This woodcut shows a traditional clothes peg and one version of many newly patented clothes pins, ca. 1860. Shakers invented the one-piece wooden clothes peg in the 1700s. Previously, laundry hung on bushes, tree limbs, or lines to dry. (Bettmann/Getty Images)

See also Dustpan; Eggbeater; Gridiron for Cooking; Mason Jar; Sewing Pattern; Toothpaste

Further Reading

Bencini, Robert F. 2010. *Ms. Inventor: Circular Saws, Flat Brooms and Clothespins: The Remarkable Inventions of Ann Lee*. Brandon, OR: Robert Reed.

Coal-Mining Technologies

Soft coal, or bituminous coal, is a combustible, sedimentary rock primarily used as a cheap and dirty energy resource outside of cities or in trains. Hard coal, or anthracite, is clean and smokeless and used in cities, often to replace wood. In America, commercial coal mining began during the 1740s in Virginia. Coal mining is categorized in two major ways; it can be mined from the surface or underground.

Types of surface mining involve strip, auger, open-pit, and mountaintop removal. There are two subcategories for stripmining: area and contour. The types of underground mining are: room and pillar, longwall, shortwall, continuous, and blast. Each of these mining processes involves different tools. Underground, the tools often used are: the longwall machine, continuous miners, roof bolters, shuttle cars, underground rail, ventilation fans, rock dusters, and scoops. Aboveground,

the equipment used includes: draglines, shovels, loaders, haul trucks, and other vehicles.

Stripmining can be done in areas or contours. Stripmining in an area is the most common type of mining. Area stripmining takes place on flat terrain, while contour mining takes place on steep terrain. Stripmining involves removing layers of minerals. Auger mining is a supplemental mining technique and is done on hillsides. Auger mining is boring near horizontal holes to recover specific areas of coal. Open-pit mining is used when multiple seams of coal lie in one location, and these tend to be vertical seams. The operation tends to stay in one area, deepening and widening the hole. Mountaintop removal is mostly used in areas that require major topographical change. It involves removing an extreme amount of overburden, or extra material, to reach coal seams. The overburden is usually placed into a nearby valley to even out the levels of the two areas.

Underground mines are named based on modes of access; hence drift mines are entered horizontally into the side of a hill. Slope mines begin in a valley bottom with a tunnel sloping down to the coal to be mined, and shaft mines involve a vertical shaft with an elevator taking miners from the surface down to the coal. Room and pillar is the oldest form of underground mining. In room and pillar, mining is done in a vertical underground area, leaving supports unmined.

Longwall is similar to room and pillar except there are no supports left behind. A longwall machine digs a long hole, supporting only the roof above itself. The roof behind it may cave in and is removed on a conveyor following the machine. For continuous mining, a machine mines until it reaches the end of a hill, and the material is excavated afterward. Blast mining is mining with the use of explosives. This is very risky and is usually only done if a tunnel must be built and bedrock sits in the way.

Early coal mining took place very near to the surface. It used either open-pit or room-and-pillar mining techniques, using workers to dig. The use of open pit and room and pillar, while only 40 percent effective then, was enough to spark the Industrial Revolution, where the invention of the steam engine called for even more coal. Underground mines required, and were constantly tested for, firedamp. To clear out firedamp, the mines were ventilated by fires or stream fans at the bottoms of vertical shafts. The use of wood to support the roof and prevent it from caving in came about around 1800. Coal mining remained unaffected by most inventions during the Industrial Revolution, as it was not cost-effective to power any relevant machinery. However, steam-powered draining machines helped remove water from flooded mine shafts. Children worked like longwall machines, fitting into small tunnels and mining only enough for their size. Either that, or they did tasks for the miners like carrying lights and shutting trapdoors. In 1889, the top-producing coal states were Pennsylvania, Illinois, Ohio, West Virginia, Iowa, and Alabama.

There were many miner strikes after a United Mine Workers union formed in 1890. This helped bring high wages and many benefits for miners. Miners risked cave-ins, floods, gas explosions, chemical poisoning, and electrocution.

Pockets of gas are known as “damp.” There are many different types of damp. Black damp consists of nitrogen and carbon dioxide and can suffocate miners. Firedamp is flammable gas that sometimes causes coal dust to ignite. Afterdamp is the gas left after an explosion of firedamp. Stinkdamp is usually hydrogen sulfide gas, which is toxic and explosive. Whitedamp combines all of the damps and is a toxic, explosive gas with no smell. Because of all the firedamp explosions

and other mining incidents, there was the invention of the safety lamp, which detected but would not ignite firedamp. Most safety lamps worked by restricting air-flow to a candle. The first lamps required constant power to pump air through water to filter out any damp. They were heavy in water weight and required to be held level to even work. There was also a lamp that provided light with sparks, which, after an explosion, prove capable of lighting firedamp. The Davy, Geordie, and Clanny lamps were standard safety lamps that had wire gauze filters around them. They would burn brighter when near firedamp. They failed to provide significant light, and they could still ignite firedamp, so they were mostly used as a detection system. Other firedamp-proof lights included jars of fireflies or bioluminescent fish scales. Finally, the electric lamp debuted in 1910.

There was great need for coal to power many inventions during the Industrial Revolution. Soft coal was a cheap source for powering steam engines and hot enough to make coke for steel. Coke is a fuel with few impurities and high in carbon; it is made from bituminous coal and is low ash and low sulfur. It produces high heat and no smoke. Melting iron and coke produces steel.

When exposing coal seams, we run the risk of causing underground fires that can leave the surface uninhabitable. Mining coal seams can affect groundwater, raising acidity. Burning coal also puts chemicals into the air that can lead to acid rain, and most notably, a carbon dioxide increase in the atmosphere. Coal is a nonrenewable resource.

As of 2016, most coal is stripmined with the use of heavy machinery. A notable piece of machinery is the Bagger 293, a bucket-wheel excavator, which holds the record for being the largest terrestrial vehicle. People are not exposed to dangerous, unventilated mineshafts when machines mine for coal aboveground.

Coal has become less effective as a power source, but it generates 30 percent of U.S. electricity. Mines are approaching the end of their useful life as natural gas and other alternatives take hold. In 2016, 25 percent of coal producers filed for bankruptcy. In 2009, the United States produced 973 million tons of coal, still the second-highest country in production. While

coal may be phased out of our energy supply at some point, coal was a stepping-stone we used to reach toward even better materials to provide us energy.

Peg A. Lamphier

See also Gold-Mining Technologies

Further Reading

- Adams, Sean P. 2014. *The American Coal Industry, 1790–1902*. London: Pickering & Chatto.
- Addy, John. 1986. *A Coal and Iron Community in the Industrial Revolution, 1760–1860*. Harlow: Longmans.
- Bise, C. J. 2013. *Modern American Coal Mining: Methods and Applications*. Englewood, CO: Society for Mining, Metallurgy and Exploration.

Coil Magnet/Electromagnet

The coil magnet, or electromagnet, is essentially a bar of iron wrapped with wire. When electric current is applied to the wire, it produces a magnetic field. Electromagnets can be used to lift or move objects, and because their magnetism can be controlled as the current is turned on and off, they can function as switches.

The first practical electromagnet was built in 1825 by English scientist William Sturgeon (1783–1850). His apparatus consisted of a seven-ounce curved bar of magnetized iron wrapped loosely with 18 turns of bare copper wire. Sturgeon coated the magnet with varnish to prevent it from shorting out with the uninsulated wires. The electromagnet was able to lift a 9-pound piece of iron, but the magnetic fields quickly collapsed, making Sturgeon's apparatus little more than a tool for demonstrating principles of electricity and magnetism.

American engineer Joseph Henry (1797–1878), a pioneer in the fields of electricity and magnetism, was intrigued by the possibilities of Sturgeon's electromagnet. He tinkered with the design, using cotton-wrapped insulated wire instead of bare copper, and he tightly wrapped several hundred turns of wire around the iron core. The result was a very strong electromagnet, much more powerful than Sturgeon's.

Meanwhile, other scientists, notably Dutch researcher Gerard Moll, were also working on making large electromagnets. Some of Moll's work was published in the fall 1830 issue of the *American Journal of Science and Arts*, but Henry had been slow to document his work and only managed to have an extract of a letter to the journal's editor, Benjamin Silliman (1779–1864), published in the appendix.

During the 1830s, Henry built a number of large electromagnets, including a 21-pounder that could lift 750 pounds. His most famous electromagnet was the one he built in 1830 for Silliman, then a professor of science at Yale. The monster magnet, which came to be known as the "Yale magnet," weighed an impressive 82-and-a-half pounds and could lift more than a ton.

Moll's electromagnets were supersized versions of Sturgeon's original, and both required large batteries. What differentiated Henry's improved electromagnet from the other designs was that he could power his electromagnets with small batteries. Henry constantly experimented with getting the most performance from small power sources. He discovered that by connecting many small batteries in a series, rather than using one large battery, he could get enough power to send a signal down a 1,060-foot length of wire and ring a bell.

The small power source was what made Henry's electromagnets so useful. They were used in the creation of the first electric doorbells (credited to Henry), as well as in telephone speakers and as relays in long-distance telegraphy.

Karen S. Garvin

See also Electric Doorbell; Henry, Joseph; Telegraph

Further Reading

- Moyer, Albert E. 1997. *Joseph Henry: The Rise of an American Scientist*. Washington, D.C.: Smithsonian Institution Scholarly Press.
- Schiffer, Michael B. 2008. *Power Struggles: Scientific Authority and the Creation of Practical Electricity Before Edison*. Cambridge, MA: MIT Press.
- Standage, Tom. 2014. *The Victorian Internet: The Remarkable Story of the Telegraph and the Nineteenth Century's On-line Pioneers*. New York: Bloomsbury.

Colgate, William (1783–1857)

Inventor and businessman William Colgate's efforts and innovations in the field of personal hygiene had a lasting impact on American society. A deeply religious man, he dedicated much of his life and wealth to the church.

William Colgate was born on January 25, 1783, in Kent County, England, to Robert Colgate, a farmer, and Sarah Colgate. Robert Colgate was an outspoken supporter of the American pursuit of independence, and his public support for the rebellion led to continuing harassment by British authorities. In March 1798, after being warned by family friend Prime Minister William Pitt that they were in imminent danger of being imprisoned, the Colgate family left England for the United States, eventually settling in Maryland. Robert Colgate formed a partnership with a local man and set up a soap-and-candle business in which his son, William, helped.

When the partnership dissolved, Robert sought to return farming while William pursued business on his own. However, lacking sufficient capital, William's first venture failed. Undeterred, in 1804, William Colgate headed to New York City to make another attempt. He soon found work with a soap maker, working with Slidell and Company. He expanded his knowledge of the soap business, and when their business shut down after just two years, he struck out on his own, establishing an operation that made and sold starch, soap, and candles. He achieved immediate success, utilizing a number of innovations, including the introduction of perfumed soap to the American consumer. Colgate also made individual bars of soap available to customers and introduced the first standardized bars of the same size and weight. At one point, the company's product line featured Pale Soap, White Windsor, and Honey brand soaps as well as Pearl Starch and a variety of shaving soap products.

Colgate pioneered the use of newspaper advertising; the first Colgate ad appeared in a New York newspaper in 1817. He also was willing to expand more broadly than was the norm, first opening a starch factory in Jersey City, New Jersey, in 1820. In 1847,

going against all conventional wisdom, he moved his company from the Dutch Street headquarters it had outgrown in the middle of New York City to a Jersey City location.

While the company thrived and expanded, Colgate also led a full life as a citizen in the greater New York area. He married Mary Gilbert in 1811, and the couple had three sons. He often told a story about meeting a canal boat captain just as Colgate was preparing to go off on his own. The captain told him that someone was going to be the leading soap maker in New York and that it could be Colgate if he made an honest, quality product while also giving God his due. Colgate said he took those words to heart, seeking to produce nothing but quality products while also promising to tithe a generous portion of his wealth to the church. He had been baptized at the First Baptist Church of New York and was an active Baptist, known as Deacon Colgate to other church members. In addition, he served on the board of managers of the American Bible Society and as its treasurer. Later splitting with that organization, he helped found the American Bible Union in 1850, where he also served as treasurer. Colgate and his family were active and generous supporters of Madison University in Hamilton, New York, and in 1890, long after his death, it was renamed Colgate University in recognition of his and the family's longtime support.

William Colgate died on March 25, 1857, in New York. He is buried in Brooklyn, New York.

William H. Pruden III

See also *Vol. 1, Sec. 2: Dental Floss*

Further Reading

Challies, Tom. 2013. "The Philanthropists." <http://www.challies.com/articles/the-philanthropists-william-colgate>, accessed August 22, 2018.

Chester, Gerald R. "Starting Right." <http://strategies-work.net/publications/Papers/Starting%20Right.pdf>, accessed August 22, 2018.

Williams, Rick, Jr. "The Story of Colgate." <http://www.seanseahsg.com/the-story-of-colgate-one-of-the-best-business-built/>, accessed August 22, 2018.

Colored Female Free Produce Society

The Colored Female Free Produce Society (CFFPS) grew out of the desire of many Americans, Northern and Southern, to decrease their own complicity with slavery. One method was to boycott goods such as sugar, cotton, and rum that were either harvested or manufactured by enslaved persons. Products that were not made by slaves were considered to be “free,” prompting some antislavery activists to organize around the idea of “free produce.” Abolitionists sought to decrease the market demand for products made by involuntary laborers by refusing to buy slave-made goods. The CFFPS was a product of this moral, humanitarian reform impulse of a group of dedicated African American female abolitionists in the Philadelphia area.

In a widely read 1811 essay, Long Island Quaker Elias Hicks (1748–1830) wrote that no one could “plead the necessity . . . to indulge themselves in the luxuries raised by the labor of slaves.” Hicks was echoing the sentiments of Quaker John Woolman (1720–1772) who had championed the “free produce” ideology as early as the 1770s. Dozens of free produce organizations had been formed by the start of the 1830s.

Black abolitionists in Philadelphia formed a distinct group in 1830 called the Colored Free Produce Society of Pennsylvania. Black women in the movement, a majority of them members of Bethel African Methodist Episcopal Church, broke off to create the Colored Female Free Produce Society in 1831. This group preceded the widely recognized Philadelphia Female Anti-Slavery Society, founded by Lucretia Coffin Mott (1793–1880) and other prominent female Quaker abolitionists, by two years. Among many similar reform groups, black and white women were compelled to create their own organizations when they encountered sexism in male-led organizations. Many historians trace the beginning of the women’s rights movement to these groups, which created for women a platform for public speaking and activism, as well as awareness of gender-based oppression.

The Colored Female Free Produce Society worked toward its goals through public promotion of its ideals, beseeching women, as household managers, to take

the moral high road in their purchasing habits. One of the earliest free produce advocates in the United States was a Pennsylvania woman named Alice Jackson Lewis, who spoke publicly about free produce at the turn of the century, encouraging her fellow Quakers to refrain from using sugar produced in the West Indies by slave labor. At this time, women were not supposed to engage in public speaking or to speak to gender- or racially integrated groups. Thus, the rhetorical cause of free produce offered a unique opportunity for women to speak on what was to many men an acceptable topic. For many black abolitionists, an obligation to abstain from slave-made goods seemed both a personal and political imperative. Many Americans joined the free produce movement, including well-known speaker and writer Frances Ellen Watkins Harper (1825–1911) and the prominent free black Forten family of Philadelphia.

The CFFPS also actively promoted merchants who dealt in free labor goods, advertising on their behalf in addition to patronizing their stores. Members were expected not only to abstain from purchasing slave-made goods in their own lives but to set an example to the larger abolitionist community and in their regions. Free produce fairs were held in New York and Midwestern states, where attendees could buy literature about the movement and merchandise branded with abolitionist rhetoric, including the slogan “Am I not a woman and a sister?” Gender-based slogans not only invoked a unity of femininity in hopes of adding more members to the cause but also played on the abolitionist notion that slavery damaged both free and slave women. Lydia White ran a successful free produce store in Philadelphia for 16 years. Nevertheless, few of these stores lasted beyond 1840, and critics rejected the free produce cause as idealistic. While little documentation has survived about the members of the CFFPS, what remains points to a legacy of staunch abolitionists among black and white American women. Grassroots organizations such as the free produce societies of the 1820s and 1830s served as a springboard for many women into a career of activism.

Kristin O’Brassill-Kulfan

See also *Vol. 1, Sec. 2: Lowell Mill System*

Further Reading

- Brown, Ira V. 1978. "Cradle of Feminism: The Philadelphia Female Anti-Slavery Society, 1833–1840." *The Pennsylvania Magazine of History and Biography* 102 (April): 142–66.
- Faulkner, Carol. 2007. "The Root of the Evil: Free Produce and Radical Antislavery, 1820–1860." *Journal of the Early Republic* 27, no. 3 (Fall): 377–405.
- Hicks, Elias. 2011. *Dear Friend: Letters and Essays of Elias Hicks*. Edited by Paul Buckley. n.p.: Inner Light, 2011.

Colt, Samuel (1814–1862)

American gun inventor and manufacturer Samuel Colt significantly changed the American market for hand-guns, improving both accuracy and safety in a manner that made Colt a watchword for quality.

Colt was born in Hartford, Connecticut. His father, Christopher Colt, was a textile manufacturer, and his mother was Sarah Caldwell Colt. Sam Colt gained an interest in finding out how things worked, taking them apart to discover how they functioned. He seems to have developed this interest through two sources: going to his father's textile mill in Ware, Massachusetts, and working at a neighbor's farm. Interestingly, among the things he took apart were his father's guns and rifles.

He attended Amherst Academy briefly to study navigation when he was 16; he was asked to leave because of his behavior. His father sent him to sea on the *Corvo* to learn navigation firsthand. The trip lasted nearly a year. It was at sea that he first came up with the model of a six-barrel cylinder with a locking pin and barrels. Aboard the *Corvo*, Colt developed a keen interest in the ship's wheel. It was his genius to apply the wheel's ability to spin or be locked in a fixed position, using a clutch, to firearms. He thus created a single-shot gun that could fire six bullets in rapid succession. He carved the model out of wood. Later, he swapped out the rotating barrels for a rotating cylinder that held the bullets.

Colt received a British patent in 1835 and an American patent in 1836. Soon after, he founded his own company in Paterson, New Jersey—the Patent

Arms Manufacturing Company. However, Colt was shrewd enough to keep the patents to himself, filing for them as an individual. The weapons he had improved were used in settling the frontier and in the battles during the process. However, initially, sales were slow. The Mexican War of 1846 to 1848 spurred sales as the United States government placed an order for 1,000 Colt revolvers. This success led eventually to the opening in 1855 of Colt's enormous manufacturing plant, then the world's largest private weapons factory. The factory was not just large; it also used the most advanced manufacturing methods. The Colt revolver became the most famous gun in the world and was used during the American Civil War (1861–1865). Colt was a strong and clever promoter. Perhaps he had gained that skill during his two years as the host of a road show that promoted nitrous oxide. "Dr. Coult," as he termed himself, made enough money to fund his perfection of the Colt revolver and to hire gunsmiths to make prototypes.

Before this success, there had been a business failure on Colt's part. First, the army had rejected the use of Colt's weapons because it deemed a percussion cap to be too new and possibly unreliable. Even though Colt had sales in Texas and Florida during the Second Seminole War (1835–1842), they did not raise the money that Colt needed to put on a prosperous front for potential clients. Colt was reduced to a sales agent when the shareholders took over his company. When the company began to fail, he joined forces with Samuel F. B. Morse to install a waterproof cable in the Atlantic Ocean. Unfortunately, the line was abandoned after being built from the New York Merchant's Exchange to Sandy Hook, New Jersey, but the inventors had proven that a cable could send electricity underwater.

Colt recovered from these setbacks and founded his new company in Hartford, Connecticut. Elisha K. Root (1808–1865) became his manager. Root was mechanically minded and hired competent, innovation-minded engineers and mechanics. The Colt Patent Fire-Arms Manufacturing Company also opened a branch in England. This was when Colt became a standard for quality. As a great promoter, Colt made his brand part of the great American myth, even having the artist George Catlin put the Colt gun into what became iconic American paintings.

The Civil War led to a great increase in sales. Colt sold over 100,000 weapons to the Union side. However, the strain of the increase in sales and the longer hours helped end his life at 47. His wife inherited his company, and Root continued as manager until 1901, when the company was sold. It continues its operation in Hartford, Connecticut, today. Interestingly, Sam Colt never fired a gun at any human being, although his brother murdered a man with a Colt weapon.

Frank Salamone

See also Colt Revolver; Repeating Rifle

Further Reading

- Adler, Dennis. 2008. *Colt Single Action: From Pater-
sons to Peacemakers*. Edison, NJ: Chartwell
Books.
- Evans, Harold, Gail Buckland, and David Lefer. 2004.
*They Made America: From the Steam Engine to
the Search Engine: Two Centuries of Innovators*.
Boston: Little, Brown and Co.
- Hosley, William. 1996. *Colt: The Making of an Ameri-
can Legend*. Amherst, MA: University of Massa-
chusetts Press.
- Tucker, Barbara M., and Kenneth H. Tucker. 2008.
*Industrializing Antebellum America: The Rise of
Manufacturing Entrepreneurs in the Early Repub-
lic*. New York: Macmillan.

Colt Revolver

Samuel Colt (1814–1862) got the idea for a multiple-shot revolver when he was a teenager. Six years later, Colt patented the revolving gun and founded the company that would mass-produce it.

Colt was born in Hartford, Connecticut. When he was 10 years old, he worked in his father's dyeing and bleaching business and learned about chemistry. He didn't like school, but he liked to read about guns. He took apart several single-shot pistols to see how they were constructed and how they worked.

Modern guns fire a cartridge that contains a bullet, gunpowder, and an explosive cap. Guns used in the early 19th century required that each component be loaded manually. Gunpowder was poured down the

barrel of a flintlock-style gun, followed by a steel ball. A clamp called a "lock" held a piece of flint. When the gun's trigger was pulled, the flint struck a metal plate and sparked. The spark ignited the gunpowder, sending the steel ball down the barrel. The load-reload process was slow, and only one shot could be fired per load.

Many had tried to produce a multiple-shot fire-arm. Variations included multiple-barrel guns or multiple chambers, but none were dependable. The goal remained a multiple-shot firearm that was accurate and reliable.

Colt was a deckhand on a cargo ship when he was 16. During the yearlong, round-trip voyage from Boston to Calcutta, Colt watched how the ship's wheel worked. The wheel turned on a ratchet-and-pawl system. When the wheel turned, a gear with teeth rotated. A pawl, or lever, slid over the gear's teeth as long as the gear moved in one direction. If the direction of the wheel reversed, the pawl locked the gear in place, preventing movement.

While on the voyage, Colt carved a wooden gun with multiple chambers in a cylinder that revolved. When Colt got back to Boston, with some financial help from his father, he hired a gunsmith to build a metal prototype. The prototype exploded upon firing. Powder leaked between the chambers, so instead of firing one at a time, several exploded at once.

Colt worked to improve the design of the revolver. He lectured throughout the eastern United States and Canada about the newly discovered gas, nitrous oxide, to raise money to produce another prototype. Colt explained the properties of laughing gas and gave demonstrations using audience member participation. His lectures were very popular.

Colt made improvements to his earlier design. The partitions between the chambers were strengthened to eliminate crossover firing. When Colt had enough money, he gave this design to a different gunsmith in 1835. This prototype worked.

The Colt revolver had a revolving cylinder with six openings or chambers. Each chamber was loaded with gunpowder followed by a lead bullet. The bullet was pushed into a chamber by a rod under the barrel. Pulling the gun's hammer rotated the cylinder. As a chamber lined up with the barrel, it locked in place. The hammer released when the trigger was pulled.

The hammer struck a percussion cap, which ignited the gunpowder and pushed the bullet down the barrel.

Colt's improved design received patents in England and France in 1835 and one in the United States (patent number X9430) in 1836 for the revolving gun. Once Colt had a patent, he found it easier to obtain investors' money to build a factory. The Patent Arms Manufacturing Company in Paterson, New Jersey, opened that year.

Customers included the newly formed Texas Rangers law enforcement agency, but orders were slow. Many were skeptical of the new technology, including the U.S. government, which chose to continue using single-shot pistols. The economic panic of 1837 did not help with sales. The company declared bankruptcy in 1842 and closed.

But Colt continued to promote the revolver. He gave demonstrations on how the gun worked. He presented gifts of engraved revolvers to legislators and other decision makers.

Five years after the Paterson plant closed, the U.S. government needed weapons to fight the Mexican-American War (1846–1848). The government placed an order with Colt for 1,000 revolvers. Colt contracted with Eli Whitney Jr. to fill the order in Whitney's Connecticut factory. This increase in sales gave Colt enough money to rent a factory in 1847 for manufacturing guns. He built a new factory in Hartford, Connecticut, in 1852. It was state of the art, with gas lamps and a ventilated work area. Workers were paid \$5 a day and given houses to live in.

The innovative machinist at the factory, Elisha K. Root (1801–1865), built many of the machines that produced gun parts. Parts were measured and were very similar in size and shape, but a worker finished or buffed parts as needed to assemble a gun.

Colt attended the first World's Fair in London in 1851 and the first World's Fair held in the United States in New York City in 1853 to promote the revolver. Colt made improvements to the revolver's design and received additional patents in 1850 and 1859. Colt died in 1862 at age 47, and Root became president of the company.

The revolver's design changed over the years. The single-action gun that required that the hammer be

cocked by hand and the trigger pulled to fire became the double-action revolver in which pulling the trigger moved the hammer back, rotated the cylinder, and released the hammer to fire the gun. Cartridges have been used for over 100 years. The revolver's dependability and accuracy remain the reasons that it is still in production.

Linda Briley-Webb

See also Colt, Samuel; Machine/Gatling Gun

Further Reading

Carter, Gregg Lee, ed. 2012. *Guns in American Society: An Encyclopedia of History, Politics, Culture and the Law*. Santa Barbara, CA: ABC-CLIO.

Haven, Charles T., and Frank A. Belden. 1940. *A History of the Colt Revolver and the Other Arms Made by Colt's Patent Fire Arms Manufacturing Company from 1836 to 1940*. New York: Bonanza Books.

Karwatka, Dennis. 1999. *Technology's Past: Volume 2—More Heroes of Invention and Innovation*. Ann Arbor, MI: Prakken.

Columbiad Cannon

Invented in 1811 by Colonel George Bomford, the Columbiad cannon was crucial in providing the United States with coastal defense in the War of 1812, as well as being an important artillery piece during the Civil War. The Columbiad was a cast-iron, smoothbore cannon that came in 7, 8, and 10-inch diameters.

Following his graduation from West Point Academy in 1805, George Bomford was assigned to an assistant engineer position at New York Harbor. In 1808, he was moved to the Chesapeake Harbor, where he served until 1810, after which he was promoted to superintendent engineer for the construction of Castle Williams at New York Harbor.

In 1811, he developed the first heavy artillery that could be utilized in defense against naval forces: the Columbiad cannon. It could fire 50-pound projectiles at up to 4,000 yards, making it effective against enemy ships. The army equipped a handful of bases around

the country with this new weaponry. Many more would have been produced if not for the high cost of manufacturing. The cannons typically weighed 15,000 pounds apiece, so maneuverability was not an option. Armies would normally place them in prime locations to ensure maximum battlefield coverage.

The Columbiad's successor, the Rodman gun, improved on several key aspects of the Columbiad. These included weight, firing distance, and the durability of the iron castings. The design was revolutionary because it utilized a hollow-cast concept. Thomas Jackson Rodman designed the hollow casting to make the cannon considerably less vulnerable to splitting and cracking—or, worse, explosion. Previous cannons, like the Columbiad, cooled from the outside inward after being fired. As their castings cooled down unevenly, they would shrink and crack. Rodman's method allowed the cannon to cool from the inside out, which made for a much more effective and durable gun. Nonetheless, the Rodman gun is essentially just an improved Columbiad. The same could be said of the Dahlgren gun, designed by John Dahlgren as a safer naval cannon.

During the Civil War, the Confederate Army used Columbiads almost exclusively, in part because they had no facilities for making their own cannon. It only had what it had confiscated from the United States when the Confederacy seceded. Columbiads were effective against Union ships that were made of iron. At the end of the Civil War, many Columbiad cannons remained at coastal military battlements. This was probably due to their weight, which made them difficult to move. They were also less effective against new weapon advancements.

Many of these cannons can still be seen adorning city halls, parks, and other government establishments throughout the country. It could be said that the Columbiad cannon serves as a symbol of patriotism. The imagery of cannons firing goes hand in hand with the shaping of the United States and freedom. Colonel Bomford could very well have conceptualized one of the most important American inventions of all time.

Sean Groves

See also Cannon, Double-Barrel; Dahlgren Gun; Military Technology (Civil War)

Further Reading

Peterson, Nancy S. 1998. "Guarded Pasts: The Lives and Offspring of Colonel George and Clara (Baldwin) Bomford." *National Genealogical Society Quarterly* 86 (December): 282–305.

Combine Harvester

The combine harvester was invented by Hiram Moore in 1835. It is a machine used to harvest grain crops by combining reaping, threshing, and winnowing in a single process.

Patrick Bell, a Scotsman, designed the first combine reaper in 1826, but he did not patent it. Nor did he put his machine into mass production, so few were available in the United States. Bell's combine was pushed by horses, while other early versions of harvesters were either pulled by ox, mule, or horse. Moore's first combine required 20 horses to pull it and cut a 15-foot swath. Later versions of Moore's combine proved wider and lighter, though combines that required 20-horse teams were common on farms, particularly in the Midwest, until the early 20th century.

In 1886, George Stockton Berry developed a steam-powered combine that ran on burning straw. These combines were the first to be self-propelled, but Berry only built seven of them, so they were exceedingly rare. In 1911, Holt Manufacturing Company produced the first gasoline-powered combine.

Today's combines are self-propelled and use diesel engines for power. A significant advance in the design of combines was the rotary design. This innovation in the agricultural machine allowed for more crops to be harvested at a higher and more efficient rate. Among the crops harvested with a combine are wheat, oats, rye, barley, corn, soybeans, flax, sunflowers, and canola. The waste left behind on the field is made up of the remaining dried stems and leaves of the crop, which is either chopped and spread on the field or left for feed and bedding for livestock.

In the early 1900s, International Harvester started making combines that were pulled by horses, and five years afterward, Case Corporation and John Deere developed combines that were pulled by tractor,



A horse-drawn combine works a California grain field in 1902. The combine harvester was invented by Hiram Moore in 1834 to ease the work of farming and expand food production for the new nation. (Library of Congress)

requiring a second engine aboard the harvester to power its functions. The Great Depression significantly affected the manufacturing of farm equipment; it halted productivity, and farmers had to return to their old methods of harvesting. Harvest time is the final critical period in making a crop, and every owner wants crops to grow safely. The Great Plains in particular have a tricky climate, and a few days of delay may bring on a windstorm or hailstorm that can greatly affect crop production. Harvesting was a dangerous task at times and required numerous hours on the field far into the night, just so a farmer could make sure that everything was running properly and efficiently. After World War II, many farms started to use tractor-drawn combines, also called “pull-type” combines. The tractors provided a source of power, whether mounted on the tractor itself or pulled along on other machinery.

One example of the farm tractor was the All-Crop harvester series made by Allis-Chalmers. These particular harvesters were able to harvest flowers as well as different grasses. These machines are still in current use and are well known for their dependability and low maintenance, but their small size isn’t well suited to the large farms of today.

A new system of leveling known as the “hydraulic hillside leveling system” was introduced in the Palouse region of the Pacific Northwest in the United States. This system allowed for combines to harvest steep slopes with as much as a 50 percent incline. The first leveling technology was developed by Holt Company, a California firm, in 1891. Modern leveling was then being addressed by the inventor and engineer Raymond Alvah Hanson, who patented the mercury switch system in 1946. Hillside leveling increases threshing

efficiency, and the system can change its center of gravity, allowing the combine to maneuver without tipping on dangerously steep hills. Another technological feature of combines is a continuously variable transmission, which can vary ground speed while maintaining a constant threshing and engine speed. This single-speed transmission also allows for seamless changes through a series of varied gear ratios. Later on, hydrostatic transmissions were introduced by Versatile in Canada. One last feature that the combine offers are removable heads designed for distinct crops. The standard header, also known as the “grain platform,” features a revolving reel with metal or plastic teeth to cut the crop. A variation on these platforms allows for faster feeding, which reduces overall costs. Some combines even have special tracks or tires with a diamond tread to prevent them from sinking in mud. Many of these tracks can fit multiple combines since the plates are adaptable.

The combine harvester is important because it allowed for more crops to be harvested as populations increased. Farm machinery like combines allowed farms to grow, because farmers could harvest more crops. This has pushed smaller farmers out of the agricultural market, particularly immigrant and black farmers. However, combines and tractors have also encouraged overfarming, which caused the great environmental disaster of the 1930s, the Dust Bowl.

In the 1980s, electronics were introduced to measure threshing efficiency, improving grain yields by optimizing ground speed and other functions. Combine harvesters are one of the most economically important of labor-saving inventions, significantly reducing the fraction of the population that must be engaged in agriculture. As the price and necessity of combines rose in the 20th century, many small farmers lost their farms to large agricultural corporations that engage in monoculture farming, grow genetically modified foods, and require massive federal farming subsidies. While it is easy to celebrate the advances that the combine brought to American farming, it is important to also consider the damage done to the environment and economy as a result of such mechanization.

Christopher Jay Lujan

See also Deere, John and Deere and Company

Further Reading

- Shiva, Vandana. 2016. *Who Really Feeds the World: The Failures of Agribusiness and the Problems of Agroecology*. Berkeley, CA: North Atlantic Books.
- Ueki, Yuko, Masami Matsui, Eiji Inoue, Ken Mori, Takashi Okayasu, and Muneshi Mitsuoka. 2012. “Turbulent Flow Characteristics of the Cleaning Wind in Combine Harvester.” *Engineering in Agriculture, Environment and Food* 5, no. 3: 102–6.

Compact Iron Stove

The compact iron stove, also known as the Oberlin stove, was invented by Philo Penfield Stewart, an American mechanic. It was patented and manufactured for domestic use in 1834. The stove had movable grates, ash sifters, hot water systems, stove top heaters, storage cupboards, and warming closets. Corrugated wood boxes, tapering fireboxes, and a few other parts of the stove allowed for more concentrated, less smoky, and more fuel-efficient fires. Additional accessories were later invented to enhance cooking and baking.

Before Stewart’s patent, most iron stoves had been intended for large industrial settings. But he felt that regular people should also be able to cook food efficiently and effectively. His compact iron stove was revolutionary as the first cooking stove to be manufactured and sold for domestic use.

Stewart’s initial design burned wood, but as coal increased in popularity, he adjusted his stoves to burn that as well. The stove was similar in size to most present-day household stoves. Its heat was produced in the main fuel-burning compartment, and a complex system of pipes and heat transfer components distributed heat to other areas. Users could therefore cook and store multiple items simultaneously, so that food could be produced more quickly and efficiently. After a few more touchups and additional improvements, the stove received prizes from the American Institute, the Franklin Institute, and the Boston Charitable Mechanics’ Association as well as endorsements from authors and other inventors.

Although the stove was popular and in high demand, it was very costly to manufacture. This

prevented Stewart from expanding his business until the Fuller and Warren stove company collaborated him. They manufactured roughly 2 million stoves. After Stewart passed away in 1868, Fuller and Warren continued to improve upon the initial design, but Stewart's natural creative spark was absent. The product's innovation and creativity slowed, causing a consistent decline in sales and popularity. Competing stoves became more popular. The Oberlin stove continued on the market, however, until the 1930s. When the Great Depression began, Fuller and Warren experienced severe declines and put an end to Oberlin stove production. It had also been made obsolete by electric and gas stoves, which were cleaner, easier, and safer to operate.

Alden Gabriel Reyes Caterio

See also *Vol. 1, Sec. 1*: Franklin Stove; “Saugus Pot”; *Vol. 1, Sec. 2*: Interchangeable Parts; Patent and Copyright Statutes; Steam Engine

Further Reading

Groft, Tammis Kane. 1984. *Cast With Style: Nineteenth Century Cast-Iron Stoves from the Albany Area*. Albany, NY: Lane Press of Albany.

Strasser, Susan. 1982. *Never Done*. Markham, ON: Fitzhenry & Whiteside.

Conestoga Wagon

The Conestoga wagon or “Dutch wagon” was an 18th-century wooden freight wagon for the commercial transport of cargo. Innovative for its ability to carry and transport tons of overland freight across long distances, it was able to withstand the difficult terrain of America's eastern landscape. With its own distinctive design built by skilled craftsman with English, German, and Dutch influences and a breed of draft horses of the same name, the Conestoga was the forerunner of the cross-country long-haul freighters, and later, the covered wagon of Americans migrating west. Covering an average of 15 miles per day, the prototypes of these mammoth wagons graced America's landscape as the key transport of goods and people, contributing

toward expansion of the Western territories in the mid-19th century and carrying supplies for building the Transcontinental Railroad.

For centuries, wagons of many shapes, sizes, and capabilities dotted the towns and rural areas of colonial America. Freight wagons were designed and altered based on the topography of a particular region. The Conestoga's early origins were near Lancaster, in the Conestoga Valley of Pennsylvania, during the 1700s and 1800s. Thousands of wagons daily traversed the route between Lancaster and Philadelphia. The Lancaster Valley area settlers were of mostly German heritage and referred to as the Pennsylvania Dutch. As ranchers of livestock and operators of lumber mills, they required a reliable way to haul their goods to nearby cities and, on the return trip, to bring back produce, textiles, and manufactured goods.

The Conestoga's reputation for durability quickly spread. The earliest mention of a specific use of the “Pennsylvania farm wagon” was during the French and Indian War (1754–1763). During the Revolutionary War and later the War of 1812, Conestoga wagons were sought after by the military for hauling cannons, munitions, and supplies.

Up until this point, large freight transport had been limited to regions of the country for which wagons had been designed. These earlier wagons lacked any major ornamentation aside from paint and no mechanical braking system, relying upon the driver to rein in the horses. The Conestoga's unique design adapted to the rough terrain with larger wheels and a suspension and braking system able to withstand long distances while carrying heavy tonnage.

Predating covered wagons that utilized a flatbed rather than the concave bed of the Conestoga and seating for the driver in front, Conestoga wagons were quite different, built in accordance to the product it would be hauling and the quality of the roads. Early Conestoga wagons were smaller and capable of hauling a load of one to three tons. As roads improved, Conestogas increased in size to carry larger payloads—upward of five to eight tons.

The bed was mounted upon the four offset wheels and covered by 24 feet of homespun heavy linen or canvas tarp, which was in turn supported by up to eight

curved bows or slats of wood fanned out over the front and back openings, suggesting the sails of a ship. The canvas was rendered waterproof with a coat of beeswax or linseed oil, or combination of both, protecting the cargo from the elements.

The front wheels stood three and a half to four feet tall and were fitted with 12 spokes each. Unlike on traditional wagons, the back wheels were taller—as much as six feet in height, with up 16 spokes. This not only afforded an easier turning radius, but less power was required to pull the wagon and cargo, lessening the impact on the draft horses. The wheels were offset on their axles intentionally so that when the wagon was loaded with heavy cargo, the weight would straighten the wheels out to support it. Conestoga tires were fabricated by blacksmiths with strips of hot iron. The heated metal was cooled with water to shrink it to fit around the wooden wheel, creating a solid tire.

Supplies needed for the often arduous journey to keep the wagon fit for travel included an ax to clear debris off the road, a tool box, a feed box for the draft horses, tar, a bucket for water, and a bucket of animal grease for the wheels.

The cargo hold was made of local hardwood, usually hickory, oak, or locust. It was painted blue and enclosed with four sides 10 to 16 feet in length, all reinforced with iron straps. The cargo hold was one of the key distinctions between the common freight wagon of the day and the Conestoga. It sloped toward the middle in a slight U shape intended to keep freight from sliding out. An Conestoga feature included an iron lever brake that, when pushed by the teamster, shoved blocks of wood against the wheels to slow the wagon down rather than relying solely upon reining in a large team of draft horses.

Early Conestoga wagons were pulled by horses of the same name, a specially bred draft horse of mixed stock, possibly sired by a Flemish stallion on a Virginia mare. Teams of six draft horses, massive in size at 16 hands high or taller and weighing over 1400 pounds, pulled the equally imposing wagons. These herculean animals pulled upward of eight tons and were hardy enough to withstand long hauls with a reputation for easy temperament, whether traveling through bustling, noisy towns or in a caravan of other

Conestoga wagons and horses. Later, as the Conestoga wagon design was adapted toward overland travel for western migration, oxen and mules proved cheaper to feed with available prairie foliage, and they were less desirable for theft by Native Americans. Over time, the Conestoga breed died out as oxen and mules replaced the costly draft horse.

Along with the special breed of horses was the skilled driver referred to as a “teamster,” who was able to manage the Conestoga horses and wagon. Teamsters hitched up harnesses to the horses and guided the team with a single rein called a “jerk line.” At journey’s end, the team’s arrival was announced with a series of bells attached to each horse. These bells also served as warnings to passing teams that another was approaching on narrow roads and around blind corners.

Unlike the covered wagon of later years, there was no seating inside the Conestoga. The teamster walked with his team or was seated on a “lazy board” that slid out from under the left side of the wagon. The driver manipulated the jerk line and operated the Conestoga’s braking system from there. Most drivers of earlier periods had operated their wagons from the right side. Conestoga wagons, with drivers on the left, set the trend that stands today of the American driver’s side on the left of automobiles.

The 1850s saw a shift in demand for freight wagons, including the Conestoga. Locomotive railroads led to the decline of the long-haul trek of overland freighting in the eastern United States and, later, with the advent of the Transcontinental Railroad, the West as well. The Conestoga contributed to its own demise by supplying the building efforts of the Transcontinental Railroad. As increased locomotive presence in the eastern United States cut travel time, the demand for the long-haul freight wagons shifted to America’s Northwest and westward, stimulated by the discovery of gold in both Montana and California. By this time, wagon makers all over the country had adapted the Conestoga’s design and ingenuity. The demand for supplies increased demand for these hardy wagons as western migration, the Civil War, and mining continued into the 1880s, but by the 1890s, Conestoga wagons were found only in areas where railroad service

was limited. Relics of the Old West, these grandes dames of the American spirit found a new life in moving pictures, lending an authentic realism while recreating the mythic image of the Western experience for many generations to come.

Cynthia J. Parker

See also Vol. 2, Sec. 1: Transcontinental Railroad; Vol. 2, Sec. 2: Chuck Wagon

Further Reading

- Bartlett, Richard A. 1974. *The New Country: A Social History of the American Frontier, 1776–1890*. New York: Oxford University Press.
- McDougall, Walter A. 2004. *Freedom Just Around the Corner*. New York: Harper Collins.
- McGaw, Judith A. 1994. *Early American Technology: Making & Doing Things from the Colonial Era to 1850*. Chapel Hill: University of North Carolina Press.

Primary Document: Excerpt from John G. Abbott's Recollections of Traveling to California by Wagon Train (1852)

Although most western settlement happened after the Civil War when railroads began to stretch west, many settlers did travel west in the 1840s and 1850s by wagon train. Such travel was made possible by the use of Conestoga wagons that were large enough to move entire households. The following is an excerpt from John G. Abbott's description of his experience traveling to California by wagon train in 1852.

Our train was increased by other emigrants joining the caravan, 40 wagons and 60 able-bodied men, all well armed. The men called a meeting to consider protection and organize. My maternal grandfather, John Gaebhart, was elected captain. He was a veteran of the "War of 1812" and had fought Indians on the front under General Jackson, and knew all the tactics of war. He was cool, considerate, and a man of good judgment.

We then made our journey over the prairies and rolling hills covered with luxuriant grass. We met many bands of Indians. They were on most friendly terms, the main object of the visits to trade dressed buffalo robes and beaded moccasins for loaves of bread. They were great marksmen, taking real pride in how accurately they could shoot their bows and arrows.

Nothing happened worth mentioning until we reached the Little Blue River, now in Nebraska. One day we saw a man approaching on horseback as fast as his horse could carry him. He was much excited and said that a band of Indians had attacked a [wagon] train of emigrants a mile ahead of us, and

had stampeded the stock and crippled several women and children. Our captain called a halt and ordered a corral formed at once. A circle of all the wagons was formed and the women and children were placed inside. By this time the Indians 300 strong were approaching, waving their blackest and buffalo robes and yelling like coyotes. They were all smeared with war paint and well-supplied with bows and arrows. The women began to scream and pray, but our captain soon silenced them. He drew the men in a line, and gave explicit orders to keep cool and not to fire until he gave the word. On the Red Devils came. When they got within a few rods of us, our captain stepped out in front of them and beckoned with his hand for them to move on. They were appalled by the bold appearance of our men and proceeded without attack.

We moved up the Little Blue River about a mile, and came to the train that had been attacked. We assisted the emigrants in getting their wagons in shape and they traveled under the protection of our train.

Shortly after this our train was attacked by the dreadful disease cholera. My father was the first victim, only living a few hours. We laid him to rest where the Emigrant Road left the Little Blue River and journeyed on. The next day we arrived at Fort Kearney. The banks of the Platte River were lined with tents, and the cholera was raging at a fearful rate, people dying on every hand. One of our companions, a young man by the name of Sheckley, died that night. We buried him the next morning and journeyed on for many miles up the Platte River. The

cholera claimed many able-bodied men, women and children by the score. This prevailed for several days. You could see men and women on bended knees asking God for the mercy of their loved ones.

The road was lined with cattle and horses. Many emigrants were compelled to lighten their loads. You could see all kinds of wagons from prairie schooners to one horse buggies standing by the roadside. These frantic travelers cast away carpentry and blacksmith tools, bedding, wearing apparel and valuable books in their mad scramble to reach the Oregon Country. We lost about 30 per cent of our train.

After getting out of the cholera belt, we left the main road and moved up the creek about 10 miles for the purpose of resting the stock. Here was the home of the buffalo. You could see them in every direction, and I believe I can truthfully say that I saw

10,000 at one time. It afforded great sport for our men to kill them, but mostly supplied us with an abundance of fresh meat. We resumed our journey and passed Fort Laramie without mishap. At Green River [WY], the men had to fix up their wagons to keep water from coming in. A few days later we had several horses stolen. Thefts of this kind were common enough through this section of the country in those days. Some laid it to the Indians, but others thought the thieves were white men.

Then we arrived at the forks of the road leading to California. About one-fourth of our train left us, among them our highly esteemed Dr. Schnell, who located in San Francisco and for many years was one of the leading physicians of that city.

Source: *Oregon Journal*, October 22, 1911.

Corn Sheller

Corn is said to be one of the more essential crops, as it does double duty in providing food for farmers and for livestock as well fuel for stoves. The act of separating the corn kernels from their cob had been a time-consuming task that farmers had had to face from the beginnings of their reliance on the crop. On August 12, 1839, Lester E. Denison earned a patent for a machine he invented—a corn sheller—that would make the said task easier and faster.

The corn sheller, usually made of cast iron, is a machine that removes dry corn kernels from a cob. The first ones were powered by manual hand crank. The farmer would insert an ear of corn into the machine, which contained cylindrical components that stripped the kernels from the cob. The cob would drop to the floor as the kernels were collected in a neighboring container. When there was an excess of cobs or kernels, farmers could sell them for profit. The corn sheller continued to improve through advancing technology and still remains an important tool for modern-day farmers.

Dannela Azul Valencia

See also *Vol. 1, Sec. 1*: Masters, Sybilla; *Vol. 2, Sec. 2*: Dickelman, Elizabeth

Further Reading

- Rolland, Donna. 2013. "Museum Talk." *The Town Crier*, October 1. <http://www.thetown-crier.com/story/2009290.html>, accessed August 22, 2018.
- Vander Schaaf, Renae B. 2017. "Corn Sheller an Important Tool on the Farm." *Farm Collector*, May. <https://www.farmcollector.com/equipment/corn-shell-ers-zm0z17mayzhur?slideshow=5>, accessed August 22, 2018.

Corset

A corset, also known as a bodice, a pair of bodies or pair of stays, is a sleeveless garment worn generally under clothing that is designed to cinch the waist of the wearer to accentuate the figure for sexual attraction, aesthetics, or act as a barrier against physical harm. Historically worn by men, women, and even children for almost 500 years, this garment has been worn as under-clothing as well as a surface or outer garment; its purpose has cycled with fashion trends over the centuries.

The earliest mention of corsets appears in ancient Egypt. The military attire of foot soldiers included a "corselet," a sleeveless outer covering made from metal, leather, or bone sewn onto linen fabric, which covered the torso and chest and was held up by shoulder straps.



A woman wears a garment meant to slim the body and make it conform to a fashionable silhouette, ca. 1899. While some men chose to wear corsets in the 17th and 18th centuries, they were practically mandatory for women of the upper classes. (Library of Congress)

Stays, or bodices, as they were referred to in 17th-century Europe, began appearing with some regularity as an undergarment for women. They were held together with a cord threaded through eyelet holes that, when pulled together, tightened the material around a woman's body. The resulting effect was designed to slenderize the waist and minimize the appearance of breasts and the chest area, or, depending on the fashion view of the period, uplift the breasts while minimizing the waist and hip area.

The type of corsets worn outside clothing during this period often were adorned with finely detailed embroidery or were encrusted with precious stones, designed for the upper classes. Materials used to make early corsets included linen with wood or steel busks, plus a panel utilized to create a stiff posture and to flatten the stomach, all to enhance and create an hourglass shape to the figure. Later 17th-century corsets were constructed of materials such as whalebone and pot metal.

By the mid-18th century, corset design styles had shifted. They were tailored shorter and worn as an undergarment to heighten the breasts. Falling out of favor for well over a century, they returned in the mid-to-late 19th century and up to the 20th century, tailored to the fashion tastes of the day. The term “corset” began appearing between 1850 and 1870. During this era, with the introduction of elastic in the construction of the corset, the use of whalebone dropped.

Fashion changes witnessed a shorter corset style as the use of crinolines increased during the American Civil War (1861–1865). In the 1880s, postwar women's clothing designs reflected a restrictive aesthetic echoing the cultural mores regarding women's place in society. Corsets played a role in this aesthetic, confining women's figures as assuredly as the society in which the clothing was worn. As a possible reaction to such strict mores, corsets as erotica appeared in rigid Victorian America. Dress designs included bodices designed to look like corsets, suggesting that the wearer was provocatively displaying a garment normally seen only in private, creating an enticing effect.

The advent of the women's suffrage movement and health concerns over the often tight-fitting undergarment prompted 20th-century women to adopt less constricting clothing. With the advent of the brassiere designed to flatten the chest in the 1910s, the corset's purpose remained to slenderize the hips. The more restrictive long skirts and corsets of the previous era that had cinched around the waist were ultimately abandoned during the 1920s. After the social, political, and economic restrictions that American women had experienced, they sought to break free of such oppressive constraints by liberating themselves from restrictive clothing. Nonetheless, variations of the traditional corset remained a staple in women's wardrobes until World War II.

Cynthia J. Parker

See also *Vol. 1, Sec. 2: Cotton Sewing Thread; Vol. 2, Sec. 1: Amalgamated Clothing Workers of America (ACWA)*

Further Reading

Hennessy, Kathryn, ed. 2012. *Fashion: The Definitive History of Costume and Style*. New York: DK.

- Tortora, Phyllis G., and Keith Eubank. 2004. *Survey of Historic Costume*. 3rd ed. New York: Fairchild.
- Willett, C., and Phillis Cunningham. 1992. *The History of Underclothes*. 2nd ed. New York: Dover.

Coston, Martha (1826–1904)

Martha Hunt Coston was an inventor and businesswoman who developed a series of maritime signal flares used by the United States Navy, shippers, and maritime insurance firms. The navy made extensive use of her flares during the Civil War.

Coston was born in 1826, in Baltimore, Maryland, but moved to Philadelphia in the 1830s. At the age of 16, she married Benjamin Franklin Coston, who was already a promising inventor. The couple moved to Washington, D.C., where Coston oversaw a “pyrotechnics laboratory” for the navy. Despite his hard work and creativity, he never received the promotions or pay raises he was promised, or full compensation for the patents he secured. Years of inhaling dangerous chemicals on the job also left him in poor health. Benjamin died in 1848, leaving Coston a young widow with four children and enormous debt.

While sorting her late husband’s papers, Coston was searching for devices to potentially patent and sell. She discovered an unfinished idea for a system of signaling flares. Although her husband had left no specific recipes for her to follow, she began experimenting with various chemical compounds. With help from her husband’s navy colleagues and chemists, Coston spent 10 years perfecting flares that were bright enough and long lasting but also convenient to use, with a coded combination of colors. In 1859, Coston patented a pyrotechnic night signal and code system. The patent was actually issued in her husband’s name; she was listed as administrator of his estate. Her first customer was the U.S. Navy, and as she waited for Congress to agree to purchase her patent, she sailed to Europe, hoping to convince the Royal Navy and the French Navy to adopt the Coston Night Signals. She was forced to return to the United States prior to the Civil War to persuade Congress to purchase her patent, which it did—for \$20,000 (only half the amount she had originally demanded).

Once the Civil War began in 1861, the navy began placing large orders for Coston’s Night Signals. Unfortunately, Coston’s manufacturer—feeling patriotic—decided to close his factory, raise a regiment of volunteers, and join the army. The secretary of the navy intervened, persuading General Winfield Scott of the U.S. Army to order the manufacturer released from his enlistment so that he could reopen his factory. The crisis averted, Coston returned to Europe to promote the flares and entice foreign governments to purchase her patent. Coston continued to improve the system, receiving a patent in her own name for a twist-ignition device in 1871. She also continued to seek \$120,000 in delayed payments from the U.S. Navy for equipment provided during the Civil War. She would eventually receive \$15,000. Coston flares were soon mandatory equipment for every station of the United States Life-Saving Service. Coston died in 1904, but the company she had founded remained in business until the late 20th century.

Kathleen Barker

See also Dix, Dorothea; Military Technology (Civil War); Mitchell, Maria

Further Reading

Drachman, Virginia. 2002. *Enterprising Women: 250 Years of American Business*. Chapel Hill: University of North Carolina Press.

Cowboy Hat (Stetson)

The cowboy hat, iconic headwear of generations of American cowboys, was the inspired invention of a second-generation American hat maker: John Batterson Stetson (1830–1906). Stetson forever turned the image of the open-plains laborer on horseback into a cowboy with the single most identifying piece of clothing: the cowboy hat.

Born of necessity, cowboy hats, also known as “beaver lids,” “boleros,” or “sombros,” did not start out as the version typified in American movies and television shows. Before the cowboy hat as we know it today, with cowboys coming from differing ethnic groups, their headgear usually reflected the country or

U.S. region from which they hailed. Early cowboys, also known as vaqueros, wore Mexican sombreros; an East Coast transplant might wear a Boston bowler from the Atlantic seaboard, and a coonskin hat might be the choice of a native of the frontier. Former Civil War Union or Confederate soldiers might sport a military uniform cap. That all changed after Stetson.

Before cowboy wear became a fashion statement emulated by American boys and girls and the symbol of masculinity in the imaginations of adults, it served a function for extreme conditions in another era. Like all cowboy apparel, each piece had a purpose aside from its aesthetics. Sashes around the waist helped hold up sagging britches or were used to tie the legs of a calf for branding. Bandanas, often repurposed from printed cloth flour sacks and hand sewn by the cowboy, served to mask faces during dust storms or to filter muddy drinking water.

Stetson, unable to compete with an established family of hat makers in his area, headed west during the migration after the American Civil War. While on the open trail, as legend has it, he demonstrated to his fellow travelers the process by which his family made their signature hats. With all the materials assembled—animal hair, fur, and/or wool—he set about matting it together. He then pressed the matted felt flat and shaped the pressed material over a mold, creating a basic hat design. Stetson then thoughtfully altered the crude design of prairie creation into a style especially suited to the unique needs of the men traveling upon the open range: he gave it a wide brim to shield them from harsh sunlight, a watertight crown that sat snugly upon the wearer's head and, when necessary, held water for a thirsty horse. It was not long before Stetson's unique design caught the eye of a passing cowboy and, with that, Stetson sold his first hat, christened Boss of the Plains.

Recognizing a need for his unique hats, Stetson opened a factory in Philadelphia, Pennsylvania, and between 1870 and 1970, the John B. Stetson Company produced headwear for men and, by the late 1800s, women too. Basic styles were either brimmed or not, with additional flourishes added to women's hats by the 1930s. The crease design variations in the crowns of men's hats might signify different regions of America,

but none of Stetson's hat designs was as iconic as that of the cowboy hat.

Stetson cowboy hats were the ones to wear for movie and television icons from the earliest days of silent films. Stars such as Tom Mix and Gene Autry often designed their own unique touches for their hats. Autry had a signature crease pattern with its own name: the Autry crease. Roy Rogers, too, developed his own signature crease, making his cowboy hat uniquely his own. William Boyd, a.k.a. Hopalong Cassidy, wore a big-brimmed Stetson; Roy Rogers wore an unassuming white one.

After World War II, the popularity of covering one's head declined, and the John B. Stetson Company closed its Philadelphia factory in 1971. The Stetson name, now licensed to another company, lives on, along with the iconic brand it created—and the most recognized symbol of the great American West, the cowboy hat.

Cynthia J. Parker

See also Machine/Gatling Gun; Repeating Rifle

Further Reading

Cowboy Hats in History. <http://www.cowboyhathistory.org/>, accessed August 22, 2018.

Stern, Jane, and Michael Stern. 1993. *Way Out West*. New York: HarperCollins.

Tortora, Phyllis G., and Keith Eubank. 2004. *Survey of Historic Costume*. 3rd ed. New York: Fairchild.

Crumpler, Rebecca (1831–1895)

The first African American female physician in the United States, Rebecca Davis Lee Crumpler spent her adult life providing health care to poor blacks in Massachusetts and Virginia, who, if it had not been for her, would have had little access to professional medical care.

Crumpler was born on February 8, 1831, to Absolum Davis and Matilda Webber in Delaware. No photos or other images of Dr. Crumpler survive from her lifetime. In Crumpler's *A Book of Medical*

Discourses, she recalled that being brought up by an aunt in Pennsylvania known for caring for her sick neighbors influenced her to first work as a nurse in Charlestown, Massachusetts. The doctors under whom she served recommended that she study medicine. Crumpler attended the New England Female Medical College from 1860 to 1864, an unusual opportunity, as most medical colleges had not opened their doors to African Americans. At the age of 33, Crumpler became the first African American woman in the United States to earn an MD degree. The second woman was Rebecca Cole, who graduated three years later. For quite some time, historians erroneously believed that Cole was the first African American woman to become a doctor.

As the Medical College focused on training midwives, Crumpler's practice focused on the care of women and children among the poorest populations of former slaves. Crumpler stayed in Boston for a year and after the end of the Civil War moved to Richmond, Virginia, in 1865. With a population of 30,000, the former capital of the Confederacy, which had fought to keep black Americans in slavery, benefited from Crumpler's dedicated services. Were it not for her efforts, supported by the Freedmen's Bureau and assorted missionary and community groups, freed slaves would have been deprived of professional medical treatment. Along with other African American doctors, she confronted racism during Reconstruction, but as a woman, Crumpler was also a target of sexist beliefs that women belonged in the home, not in professions. Some white doctors ridiculed her, saying that the "MD" behind her name stood for "mule driver." This derision did not deter Crumpler.

After a year in Richmond, Crumpler returned to Boston, residing on African American-populated Joy Street on Beacon Hill with her husband, Arthur Crumpler. Rebecca Crumpler opened a medical clinic, where she again treated mainly women and children of color. She taught the basics of nutrition and prescribed preventive medicine for her patients. Crumpler gained a reputation as a selfless human service provider, treating patients in her house without bothering about fees for it. She also devoted her spare time to research and made copious notes about health care.

Crumpler relocated to Hyde Park, Massachusetts, after retirement in 1880–1881. To her mind, educating the public about health care was an important and developing field. All her medical experiences and notes were published in *A Book of Medical Discourses* (in two volumes) through the Boston-based publisher Cushman, Keating & Company in 1883. The target audience was women, whom Crumpler hoped to educate about the basics of health care for their families. The book was one of the first publications in the medical field by an African American, male or female.

After decades of being forgotten by the public and academia, Crumpler has been rediscovered. The Rebecca Lee Society, established in 1989 by doctors Sandra Maass-Robinson and Patricia Whitley, supports African American physicians by offering financial assistance and promotion of their work. The Association of Black Women Physicians commemorates Crumpler by giving fellowships in her name.

During the mid-19th century, when advanced education was not common even for white women, Crumpler graduated from medical school. Her life's work contributed toward the empowerment not only of black women but also of American women in general. Crumpler's diligence, honesty, involvement, persistence, and dedication underline her significance in post-Civil War America.

Patit Paban Mishra

See also Vol. 1, Sec. 2: Blackwell, Elizabeth

Further Reading

- Crumpler, Rebecca Lee. 1883. *A Book of Medical Discourses*. Boston: Cashman, Keating.
- Davis, Veronica A. 2005. *Inspiring African American Women of Virginia*. New York: iUniverse.
- Sammons, Vivian Ovelton. 1990. *Blacks in Science and Medicine*. New York: Hemisphere.
- Wells, Susan. 2001. *Out of the Dead House: Nineteenth-Century Women Physicians and the Writing of Medicine*. Madison: University of Wisconsin Press.

Cylinder Pin Tumbler Lock

The modern pin-and-tumbler lock was invented by Linus Yale Jr. He invented the lock for banks in 1851 and another for doors in 1863. In 1865, he invented the pin tumbler padlock. His designs remain the foundation of locks still used today.

The first tumbler locks date back as far as 4000 BC. This form of lock operates with two cylinders, one inside the other. The outer cylinder has springs that push on pins of varying lengths within the inner cylinder. While the lock is engaged, the pins are at irregular positions that cross between the two cylinders, preventing rotation. When a key with the correct teeth is inserted, it pushes the pins into a regular position, freeing the two cylinders and allowing the inner one to rotate inside the outer.

Linus Yale Jr. was born in Salisbury, New York, on April 4, 1841, and was a mechanical engineer by trade. He was a manufacturer and the cofounder of the Yale Lock Company. His father was an inventor and owned a lock shop, and Linus Yale Jr. became involved in the business in 1858. In 1860, he opened the Yale Lock Company, and in the same year, he died suddenly of a heart attack.

Tom Conrad Landry

See also *Vol. 1, Sec. 2:* Wheel Cipher; *Vol. 3, Sec. 3:* TOR (The Onion Router)

Further Reading

Tobias, Marc Weber. 2001. *Locks, Safes and Security: An International Police Reference*. Springfield, IL: Charles C. Thomas.

Dahlgren Gun

The Dahlgren gun was a piece of artillery used during the American Civil War by both the Union Army and the Confederate Army. The Dahlgren gun has many variant designs and was used throughout the war, seeing most action aboard naval vessels. There were two types of Dahlgren guns: shell guns and rifled guns. Shell guns possess a smooth bore, and rifled guns possess rifled bores that add spin to their projectiles, improving range and accuracy.

Union Rear Admiral John A. Dahlgren invented his gun after he saw an accidental explosion. Cast-iron cannon of the time tended to crack after they heated when fired and then cooled. Moreover, cast iron is brittle, making cannon with larger bores for larger cannonballs more likely to break and explode on firing. The accident he saw motivated Dahlgren to design a cannon that was safer and more structurally sound than Columbiad cannons. The most significant improvement that Dahlgren made on the Columbiad was a variation in its shape. Dahlgren guns had a characteristic “soda bottle” shape that allowed it to take more strain when the powder exploded.

Dahlgren’s first cannon variation was the IX-Inch Dahlgren shell gun. The IX-Inch became its most popular design, leading to the production of over 1,000 artillery pieces. It was the most versatile of all the Dahlgren gun models because it was lightweight and accurate, particularly compared to other artillery of the time. By 1864, more than 3,000 Dahlgren Guns were produced and actively used in the war. Most Dahlgren cannons were created at the foundries at Fort Pitt, Alger, Bellona, and West Point.

The IX-Inch Dahlgren gun has an average length of 131 inches, a bore circumference of 107 inches, and a trunnion diameter of 7.25 inches. The entire piece weighed around 9,000 pounds, and its effective range was about 3450 yards. Dahlgren gun artillery variants ranged from the 32-pounder that weighed 3,200 pounds with a range of 1637 yards to the XV-Inch “Tecumseh” that weighed 43,000 pounds and had a range of 2,100 yards.

Dahlgren rifled guns were nowhere near as popular as the shell guns, but the most popular rifled model was the 20-pounder rifle. It weighed around 1,340 pounds and saw service aboard various vessels. The largest Dahlgren rifled gun was the 12-inch rifle, weighing about 45,000 pounds. Most of the rifled gun variants produced after the 20-pounder saw little to no service due to firing issues and safety concerns.

Dahlgren was the first to incorporate the production of artillery pieces on a large scale, and eventually he created and produced howitzer artillery, rifles, and other gun pieces. The Dahlgren gun saw little to no action after the American Civil War as military technology advanced and newer, more effective cannons

were developed. Since new cannons were on the rise and the demand for the Dahlgren fell abruptly at the end of the war, it became obsolete. John Dahlgren passed away in 1870, and production of the cannons was discontinued after the American Civil War ended.

Alden Gabriel Reyes Caterio

See also Columbiad Cannon; Military Technology (Civil War)

Further Reading

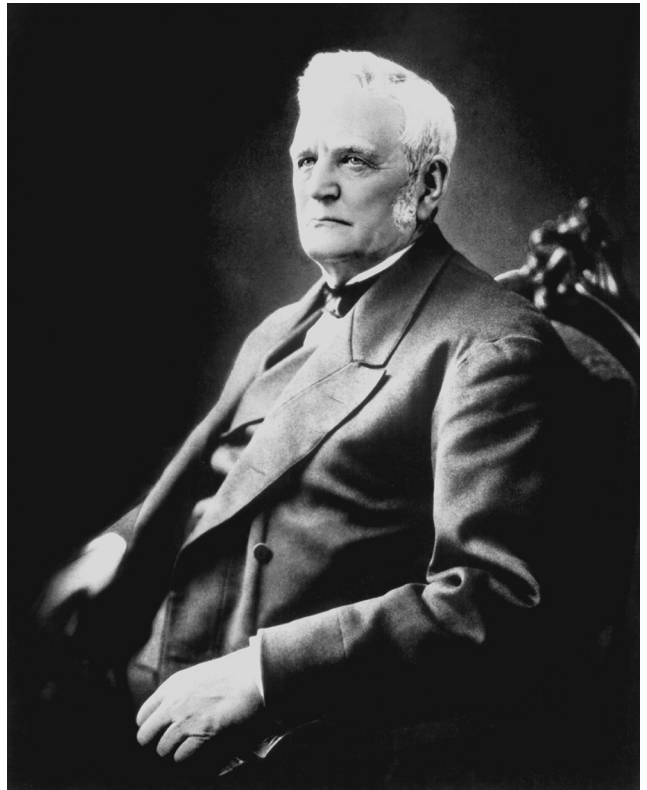
Anderson, Bern. 1962. *By Sea and by River: The Naval History of the Civil War*. New York: Knopf.
Geier, Clarence R., Douglas D. Scott, and Lawrence E. Babits. 2014. *From These Honored Dead: Historical Archaeology of the American Civil War*. Gainesville: University Press of Florida.

Deere, John (1804–1886) and Deere and Company

American inventor, businessman, and blacksmith John Deere founded Deere and Company in 1868. Deere invented the polished steel plow in 1837, which allowed Midwestern settlers to cultivate the heavy soil and tough native grasses of the Great Plains. Today, Deere and Company is an American multinational headquartered in Moline, Illinois. It produces agricultural and construction machinery and productivity software.

John Deere was born on February 7, 1804, in Rutland, Vermont, to Sarah Yates Deere and William Rinold Deere. After finishing his public school education, he turned his efforts to becoming a blacksmith. At 17, he took a three-year blacksmithing apprenticeship with Captain Benjamin Lawrence and in 1826, at 21, he set up his own blacksmith shop. A year later, he married Demarius Lamb, with whom he would have nine children.

With the recession of 1837 impairing his job prospects in Vermont, Deere headed west. Leaving Demarius to look after their then five children, Deere went to Illinois and settled in Grand Detour. He set up another blacksmith shop and a year later sent for Demarius and the children. He repaired the cast-iron and wooden



John Deere, who founded Deere and Company, developed a steel plow in 1837 that could scour the heavy western soil of the United States, which allowed farmers to plant considerably more acreage. (Deere and Co.)

plows of the local homesteaders. The plows were imports from the eastern states, which had soft, sandy soil, and so they were ill suited for the dense, rich, and clay-infused Illinois soil. The soil would stick to the blades, requiring farmers to continually stop and clear them. The blades would also break after getting stuck in matts of roots and mud. Deere's solution was to design a steel-bladed plow. Unlike an iron plow's, the smooth, steel blade easily scythed through the soil.

The plow proved immensely popular. To capitalize on its success, Deere formed a partnership with Leonard Andrus to set up a factory. By 1846, they were producing 1,000 plows a year. But that same year, the partnership fell apart, and Deere moved to Moline, Illinois, a transportation and trade hub on the Mississippi River. Deere built a new factory, and by 1855, he was producing 10,000 plows a year. In 1857, Deere entrusted the day-to-day running of the company to his son Charles but remained president until his death.

Production increased, and the company began producing other farming equipment, including wagons, corn planters, and cultivators. In 1863, a sit-down cultivator was introduced: the Hawkeye Riding Cultivator. Deere received his first patent in 1864 for the molds used in casting his steel plows. In 1875, he introduced the Gilpin Sulky plow. It was horse drawn but with a seat. Three years later at the Paris Universal Exposition, it beat 50 other plows in a field trial. The next year, the plow sold over 5,000 units. In 1881, Deere inaugurated the first factory in the United States to be lit by electricity in Rock Island County, Illinois.

Demarius Deere died in 1865, and John Deere married her sister, Lucinda, two years later in June 1867. Deere was mayor of Moline from 1873 to 1875. He died May 17, 1886, at the age of 82. Deere's company lives on well after its founder's death.

At the beginning of the 20th century, the company began producing petroleum-powered tractors, the first of which was the Dain All-Wheel-Drive tractor. Deere continued to expand into gasoline-powered tractors by purchasing the Waterloo Gasoline Engine Company of Waterloo, Iowa. In 1919, Deere sold 5,634 of its new Waterloo Boy line of kerosene-powered tractors. It introduced the first combine harvester in 1927, the first machine that could reap and thresh grains at once—reducing the time it took farmers to harvest their crops, greatly improving productivity. The company introduced the Model A and B tractors in 1934 and 1935. 1935 saw the introduction of the D1, a heavy-duty tractor for industrial use. In 1937, the centennial of the company saw revenues reach 100 million.

The company's contribution to the war effort during World War II was extensive. Charles Deere Wilman, the president of the company at the outbreak of World War II and the great grandson of the founder, accepted a commission as an army colonel. He also directed the farm machinery and equipment division of the War Production Board during the war. Around 4,500 employees of the Deere company joined the army in their own battalion. The company produced military tractors, aircraft parts, ammunition, and mobile laundry units. To produce M3 Lee and M4 Sherman tank transmissions, Deere set up a separate company, Iowa Transmission Company, at their

Waterloo Works production site. However, wartime limitation orders reduced output and what they could build. The office of production management ordered manufacturers to build at only 80 percent of 1940's production level, but they could build spare parts to keep old tractors running.

In 1947, the model "M" tractor was built at the new John Deere Dubuque Works. Two years later it became a bulldozer when designers added a front blade and named it the "MC."

This is the first of its construction equipment. The 1950s were a time of expansion. In 1956, the company bought Lanz, a German tractor and harvester maker. 1958 saw the introduction of its industrial equipment division that focused on industrial application, a turn away from Deere's agrarian equipment past. The 440 crawler was its first product. Its consumer equipment division for lawn and garden tractors and mowers was introduced in 1963. The company now produces planters, buggies, wagons, grain drills, and hay and harvesting equipment.

John Deere is the largest agriculture machinery company in the world, with production facilities in the United States and 17 countries, including China, Germany, and Brazil. It employs 67,000 people worldwide and has a valuation of over \$40 billion on the New York Stock Exchange, with revenue of over \$26 billion in 2016. Today, Deere and Company offers an extensive variety of machinery for lawn care, landscaping, agriculture, construction, and forestry, and it builds engines and productivity software. Its portfolio consists of tractors, combines, mowers, sugarcane harvesters, planters, grain harvesters, loaders, dump trucks, backhoes, dozers, excavators, and tree fellers.

Peter Magistrale

See also Combine Harvester; Mechanical Reaper; Polished Steel Plow; *Vol. 1, Sec. 2: Steam Tractor*

Further Reading

- Broehl, W. G. 1984. *John Deere's Company: A History of Deere & Company and Its Times*. New York: Doubleday.
- Collins, David R., and Steve Michaels. 1990. *Pioneer Plowmaker: A Story about John Deere*. Minneapolis: Carolrhoda Books.

Macmillan, Don, and Wayne G. Broehl. 2003. *The John Deere Legacy*. Stillwater, OK: Voyageur Press.

Sanders, Ralph W. 2001. *Ultimate John Deere: The History of the Big Green Machines*. Stillwater, OK: Voyageur Press.

Dental Chair

Dental chairs play an important role in operative dentistry. The first commercial dental chair was developed and patented by Milton Waldo Hanchett in 1848. Previous such chairs had often been designed and built by dentists themselves, mostly from household armchairs; they differed only slightly from ordinary rocking chairs. Some of the first attempts to improve them included the addition of a headrest, at first fixed and then movable, followed by the ability to change the height of the seat, and then the positions of both the back and the seat.

Milton Waldo Hanchett (1822–1904) of Syracuse, New York, developed and patented the first dental chair that combined all of these improvements. He was granted U.S. patent number 5711 on August 15, 1848, for a “surgical or dental operating chair” with adjustable elevation and tilting seat and back. It had a central supporting screw under the seat by which it could be raised or lowered similarly to a piano stool. The seat hinged in such a manner that it could be tipped forward and backward and held in a particular position. Elevation was accomplished by turning the seat on the screw, which was fixed to the seat by gudgeons at the ends of horizontally projecting arms, making possible the tipping of the seat forward and backward. The chair also had a footrest that could be elevated and at the same time brought nearer for the convenience of the patient. The entire chair was held in the desired position by means of notched iron semi-circles and a cogged wheel controlled by a winch and ratchet.

Hanchett’s dental chair was never put into production, but other dental chairs with the same design were subsequently manufactured. Hanchett’s chair, in effect, was a prototype for the commercially manufactured dental chairs from F. Searle of Springfield,

Massachusetts, in 1849. They had seats that could be adjusted vertically by a series of hinges. By tipping the seat on the front hinges, it was inclined forward, and the reverse movement was secured by the back hinges; when both hinges were operated, the whole seat could rise vertically. The different positions were attained and held by way of cogged iron quadrants. Another dental chair invented and manufactured by C. H. Eccleston from Utica, New York, had the seat positioned on steel springs that were held in place by tightening a setscrew on a retaining rod. The back of this chair, however, could be tipped forward and backward on a hinge pin exactly the way described in Hanchett’s patent. There are several other examples (including by Perkins, J. O. Whitcomb, Ask, Archer, and S. S. White) illustrating the rapid progress of the product before the implementation of hydraulic mechanisms in the modern reclining dental chair.

Stefka Tzanova

See also *Vol. 1, Sec. 2*: Dental Floss; Swivel Chair

Further Reading

Glennner, R. A. 2000. “The Dental Chair—Early Development.” *Journal of the History of Dentistry* 48, no. 1: 21–24.

Detachable Collar

A collar that can be taken off a shirt and reattached is a detachable collar. It started as a simple way to save time and energy for 19th-century housewives but became a common fashion accessory for 100 years.

Hannah Lord Montague (1794–1878) lived in Troy, New York. Her husband was a merchant and manufacturer of quality women’s shoes and a respected businessman who wore a clean shirt to work every day.

Montague was responsible for the household chores, which included laundry. Laundry in the early 19th century was definitely a chore: there were no washing machines. Water collected from an outdoor pump in a wooden bucket filled a cast-iron pot on a cookstove. The stove required wood or coal for its fire. The dirty clothes were soaked in the hot water and

then rubbed on a washboard (a rectangular wooden board with ridges). Another bucket or two of clean water was needed to rinse the clothes. Clean clothes were hung on a line to dry. It could take more than a day to wash laundry, depending on weather. Once dry, clothes such as men's shirts were then starched and ironed. Laundry was a long process.

In 1827 Montague noticed that the collar and cuffs of her husband's shirts were dirtier than the rest of them. Repeatedly washing the entire shirt seemed unnecessary. Shirts were expensive, so Montague had an idea. She cut the collar off her husband's clean shirt, sewed tape at either end of the collar, and reattached it to the selvage (a fabric's edge woven so that it doesn't fray). The next time she did the laundry, she took the collar off the shirt; washed, dried and starched the collar; and reattached it. Since the shirt itself could be laundered less frequently, it could be replaced less often, saving money. When a collar got discolored and had to be replaced, it was cheaper to buy than a shirt—about 35 cents.

There were many styles of detachable collar over the years. Some were secured with string or tape wound around the wearer's neck, but these could loosen and separate from the shirt. Other styles of detachable collars were more secure because the collar reattached with studs, pins, or buttons.

Fashionable men at the turn of the 20th century still wore detachable collars. It wasn't until after World War I (1914–1918) that fashion became more relaxed and men wore shirts that were made of softer material and had attached collars.

Linda Briley-Webb

See also Electric Stove; *Vol. 2, Sec. 1: Rotary Washing Machine; Vol. 2, Sec. 2: Washing Machine, Electric*

Further Reading

- Mullenbach, Cheryl. 2014. *Industrial Revolution for Kids: The People and Technology That Changed the World*. Chicago: Chicago Review Press.
- Pendergast, Sara, and Tom Pendergast. 2004. *Fashion, Costume, and Culture: Clothing, Headwear, Body Decorations, and Footwear through the Ages*. Farmington Hills, MI: The Gale Group Thomson Learning.

Scranton, Philip, ed. 2001. *Beauty and Business: Commerce, Gender, and Culture in Modern America*. New York: Routledge.

Turbin, Carole. 2000. "Collars and Consumers: Changing Images of American Manliness and Business." *Enterprise and Society* 1, no. 3 (September): 507–35.

Dix, Dorothea (1802–1887)

American activist Dorothea Dix fundamentally altered the American approach to treating the mentally ill. She also worked as the superintendent of army nurses during the Civil War. Dix excelled at organizational innovation for health care institutions.

Dix was born April 4, 1802 in Hampden, Maine, to Joseph Dix and Mary Bigelow. At the age of 12, she moved in with her wealthy grandmother, Dorothea Lynde, in Boston to get away from her alcoholic and abusive father. In 1821, Dix opened a school that was paid for by well-to-do families. After opening her school, she also began teaching poor children out of her own grandmother's house until poor health forced her to stop.

Dix next worked as a governess. While working for a family, Dix traveled to St. Croix and witnessed slavery there. Dix was appalled by slavery and vowed to work to end it. In 1836, she took a trip to Europe to mend her health. While there, she met other reformers who inspired her viewpoint on equal rights, specifically equal rights for the mentally ill. She spent some time with English Quakers who believed that the government should play a direct, active role in social welfare, including the care of the insane.

After returning to the United States, Dix led an investigation into those people classified as the insane poor in Massachusetts. This investigation showed that in most cases, towns worked with local individuals to care for the mentally ill who could not care for themselves and had no family to do so. Dix saw that the mentally ill were completely dependent on private individuals, which resulted in widespread abuses. In 1844, she investigated "insane asylums" and recorded the conditions in which the mentally ill were kept and the treatment they received. Her report exposed the systematic mistreatment of asylum patients.

In her investigations, she found a man who was a respected legislator and jurist who had become mentally insane in his old age. Dix had found him lying on a small bed in a basement of a country house, absent of necessary comforts. Her discoveries resulted in a bill that expanded the state's mental hospital to provide for more mentally ill people. Many members of the legislature knew the old man she had found, and in response, Joseph S. Dodd introduced her report to the state senate, which in turn authorized an asylum.

After this victory, Dix continued her investigation, traveling from New Hampshire to Louisiana and making reports to send to state legislatures and working with committees to pass bills. When Dix moved on to Illinois in 1846, she fell ill, and her investigation was temporarily put on hold. When she sent a report in January 1847, legislation was adopted to establish Illinois's first mental hospital. She continued visiting different states, calling for reform in the care of mentally ill patients.

In addition to being an activist for the mentally ill, Dix also served as superintendent of army nurses in the American Civil War, narrowly beating out Elizabeth Blackwell, the first American female doctor, for the job. At the time, nurses were not respected health care workers. In fact, female nurses were often equated with sex workers. Dix required female volunteer nurses to be plain or unattractive, 35 to 50 years old, and to dress in unadorned, dark clothing. Three thousand American women served as army nurses during the Civil War. Dix's contributions to the professionalization of nursing lay in her great talent for organization and her insistence that nurses be treated as respectable women.

Dix was also widely admired but also criticized for her insistence on treating Confederate soldiers. After Gettysburg, for example, the Confederate Army withdrew, leaving over 5,000 wounded soldiers behind. Dix and her nurses treated these men, as well as Union soldiers, on the principle that suffering men required moral treatment regardless of their personal circumstances.

After the war, Dix helped fundraise for a monument to honor the soldiers lost at Fort Monroe. She traveled the United States to review the asylums and prisons she had helped create to evaluate the damage of the war. She died on July 17, 1887, and was buried in Cambridge, Massachusetts.

Camille Michaluk



Dorothea Dix is best known for her work on behalf of the mentally ill and for serving as a superintendent of army nurses during the Civil War. For all her contributions, a crater on Venus was named Dix in her honor in 1994. (Library of Congress)

See also Civil War Medicine; Civil War Nursing; U.S. Sanitary Commission (USSC); *Vol. 1, Sec. 2*: Blackwell, Elizabeth

Further Reading

Gollaher, D. 1995. *Voice for the Mad: The Life of Dorothea Dix*. New York: The Free Press.

Double-Barrel Cannon. See Cannon, Double-Barrel

Dustpan

Most people rarely think about common, everyday household items such as the dustpan until they actually need them. The issue of what to do to transfer all the dirt, dust, and trash that was gathered by a broom into the garbage can would not be solved until the late 1850s.

On July 6, 1858, inventor Thomas E. McNeill earned a patent for the first dustpan, though African American inventor Lloyd P. Ray is associated with improving the product. On August 3, 1897, Ray earned a patent for his version, which addressed two immediate issues at hand: efficiency and the need for one to be on hands and knees to sweep the dust into the pan. Ray's version collected more dust and had a long handle. Varying patents of the dustpan came after, but Ray's is still said to be the basis for others.

Dannela Azul Valencia

See also Mason Jar; Pepper (and Salt) Shaker

Further Reading

Bellis, Mary. 2017. "Inventor Lloyd Ray Patented New and Useful Improvement in Dustpans." *ThoughtCo*, April 13. <https://www.thoughtco.com/lloyd-ray-dust-pans-4071178>, accessed August 22, 2018.

"Who Invented the Dustpan?" *Let Us Find Out*. <http://www.letusfindout.com/who-invented-the-dustpan/>, accessed August 22, 2018.

Eggbeater

Ralph Collier of Baltimore, Maryland, patented the rotary eggbeater in 1856. He designed his labor-saving kitchen invention to froth, whip, and beat eggs. Collier, a tinsmith by trade, and Alfred H. Reip, a fellow tinner and ironware manufacturer, jointly produced the tin-wire, handheld eggbeater tool. It worked when one turned a handle on top of vertically revolving gears. Collier's eggbeater revolutionized the baking industry. Prior to the invention of his eggbeater, spoons had been used to whip eggs. While this was fine for omelets, it was necessary to whip eggs properly, especially egg whites, to ensure the taste, texture, and density of baked goods.

Collier's eggbeater served as a catalyst for future eggbeater designs. British inventor E. P. Griffith's included a handle with vertically revolving gears inside of tin can. He claimed that his product equaled 288 strokes of a spoon with every turn of the tool's handle. The Dover Stamping Company redesigned the

eggbeater and marketed it as a pattern-improved tool. It became so popular that the U.K. business manufactured over 4 million of the mechanical, handheld eggbeaters popularly known as Dovers. The Dover eggbeater had the company name stamped on its mechanical gear and came with a warranty. It could be purchased in family size, hotel size, and an extra family size; on average, it cost \$1.25.

African American Willis Johnson of Cincinnati, Ohio, expanded the size of the eggbeater design with his patented rotary beater machine. His dual-acting device was an early mixing machine intended for eggs, batter, and any other ingredients necessary for baking. The Johnson hand-cranked mechanism allowed baking on a large scale; its main frame contained a driving wheel, pulley, and two cylinders. The cylinder chambers, which were equipped with spring-like whisks, could be used for two different mixtures, such as batter in one chamber and eggs in the other. Conceivably, a baker could also clean one chamber while using the other to beat an ingredient.

American engineer Herbert Johnson, working for the Hobart Manufacturing Company, took the eggbeater one more step by redesigning it as a bread dough device for wholesale bakeries. The Hobart design became an electric, free-standing commercial mixer with an 80-quart capacity. The popular kitchen appliance, which eventually became known as the KitchenAid Food Preparer, remains a standard. Ivar Jepson, an inventor working for Sunbeam Products, completed the 19th- and 20th-century evolution of the eggbeater when he invented the Sunbeam Mixmaster. Jepson's eggbeater utilized two detachable blades that interlocked when electrically operated. The Mixmaster was a mass production success for Sunbeam, even though it debuted during the Great Depression. Today, this easy-to-use electric mixer can still be found in numerous modern kitchens.

Amy Helene Forss

See also *Vol. 2, Sec. 2*: Blender; Hoosier Cabinet; *Vol. 2, Sec. 3*: Microwave Oven

Further Reading

Thornton, Don. 1994. *Beat This: The Eggbeater Chronicles*. New York: L. W. Book Sales.

Electric Doorbell

The electric doorbell was invented in 1831 by Joseph Henry (1797–1878), an engineer and inventor. The first electric doorbells were simple buzzers; bell chimes were not introduced until the early 1930s.

While experimenting with electromagnets, Henry discovered that he could use several small batteries and produce enough power to send a signal down a length of wire. Henry ran more than a mile of wire around the upper rooms of the Albany Academy and succeeded in using his electromagnet to ring a bell.

The first electric doorbells were battery operated. By 1896, a homeowner could order a doorbell kit from the Sears catalog for as little as \$2.50, which included the bell (actually a buzzer), a push button, battery, wire, and assorted hardware for installation. Batteries were gradually replaced by transformers once homes became connected to the electric grid, and by the 1920s, transformers were increasingly affordable to homeowners. The first musical doorbells were introduced in the mid-1930s and were marketed as luxury items.

Karen S. Garvin

See also Henry, Joseph; Telegraph

Further Reading

Moyer, Albert E. 1997. *Joseph Henry: The Rise of an American Scientist*. Washington, D.C.: Smithsonian Institution Scholarly Press.

Electric Stove

William Hadaway patented the first electric stove in 1897. The electric stove gradually replaced wood and coal stoves in the early 20th century.

In 1859 George Simpson patented the first electric coil system, which he theorized could be used for cooking. An early electric stove appeared at the Chicago World's Fair in 1893 as part of an electric kitchen demonstration. Hadaway's patent four years later improved upon the World's Fair stove by including knobs for automating and controlling heat. The 1920s

and 1930s rural electrification movement increased demand for electric stoves, which were considerably easier and cleaner to operate than wood- or coal-fired stoves.

Electric stoves relied on heating coils until the early 21st century, when solid-state electric cooktops became more widely available. Induction cooktops, which heat through electromagnetic induction, further innovated electrical stoves. Today, many home cooks and most commercial cooks prefer gas stoves, but the electric stove continues to command a significant market share.

Peg A. Lamphier

See also *Vol. 1, Sec. 1*: Franklin Stove; *Vol. 1, Sec. 2*: Vapor-Compression Refrigerator; *Vol. 2, Sec. 2*: Hoosier Cabinet

Further Reading

Lau, Skip. 2012. *Old Stoves Are Hot! A History of Antique Cooking Stoves*. Santa Barbara, CA: Pilot Light Press.

Electric Street Railway

The electric street railway is based on railway tracks, generally in urban areas. Each is known by a different name, depending on the region. The railways are electrically powered, usually by wires that run overhead. The wires are connected through sliding grips to the tops of the vehicles. The sliding grips are called “pantographs.” They are designed for low friction when in contact with the sliding wires, preventing wear that could cause them to break and leave the vehicle with no power.

Electric street railways have been a popular method of transportation for short distances within cities since the 1880s. The first street railways, also called omnibuses, were pulled by horses. The next versions were steam powered and used the same engines that locomotive trains did, only smaller. Then they became cable-pulled cars, which could be lighter because now they did not have to support the weight of steam engines. These cars were connected to a station

with a cable that pulled it along the tracks. After that, the cars became electrically powered.

Electric street railways have their own railway systems and dedicated lanes in cities. When electric street railways started to appear in Saint Petersburg, Russia, there were two types: battery powered and one with an overhead powering system. The second type became more popular due to its reliability. Electric street railways were popular in urban areas because they were easier to build, maintain, and run than conventional trains. Also, because they ran within cities, they had to be light. They were therefore cheaper than railcars for traditional trains.

The first electric street railway system in the United States was built in Cleveland, Ohio. By 1900, there were already close to 900 electric street railways in the country. Electric street railways were the most popular method of transportation for a few decades until the 1930s, when the Depression hit the United States. When the automobile industry expanded during the 1940s, electric street railways fell behind.

Electric railways declined in part because of the large infrastructure investment they require. An electric street railway must have a dedicated lane on streets, since they operate on rails. Also, in some cities, petroleum companies bought the electric railway companies and closed them down to encourage people to buy cars. Despite that, electric street railways still operate in many cities, including San Francisco, Boston, Cleveland, Philadelphia, Pittsburgh, Newark, and New Orleans, where they enjoy significant popularity

Peg A. Lamphier

See also *Vol. 2, Sec. 1*: Electricity, War of the Currents; Electrification, Urban

Further Reading

- Long, Raphael F. 1966. *Pacific Electric's Big Red Cars: A Pictorial Account of the Decline of the World's Largest Interurban Electric Railway System*. Universal City, CA: T. C. Phillips.
- Post, Robert C. 1989. *Street Railways and the Growth of Los Angeles: Horse, Cable, Electric Lines*. San Marino, CA: Golden West Books.

Electromagnet. See Coil Magnet/
Electromagnet

Elevator Safety Brake

“All safe.” With those words, Elisha Graves Otis (1811–1861) did two things: he calmed the astonished onlookers at the 1853–1854 New York World’s Fair after he had cut the rope suspending the platform where he had stood—and he also ushered in the modern urban skyline. He accomplished both with his introduction of the elevator safety brake.

Elevators themselves were not exactly a new invention. Devices for raising and lowering people or freight had been noted as far back as the ancient Greek engineer Archimedes (ca. 287–212 BCE). Improvements took place steadily throughout history as elevator platforms were suspended by pulleys on ropes or chains and powered by humans or animals. Steam power was utilized in elevators for hoisting coal or lumber in England’s Industrial Revolution during the first half of the century. In 1823, two enterprising London businessmen offered an “ascending room” in which paying customers could be carried high enough to observe a panoramic view of the city below.

What Elisha Otis’s demonstration proved was that a safety feature could successfully engage even if an elevator’s cable broke. In his safety brake, a metal wedge was jammed from underneath the elevator car into a channel in the guide rails if the car started to descend too rapidly. The friction between the wedge and the rail continued to build until it ultimately brought the elevator car to a stop at a comfortable rate.

The demonstration was so successful that sales of Otis elevators rose along with the equipment his company built. With his factory in Yonkers, New York, Otis was able to supply elevators for the mushrooming construction of Gilded Age skyscrapers in nearby New York City. This changed the way people lived and worked. Before this invention, richer tenants had lived in street-level apartments and poorer ones lived on higher floors, where it was more difficult to carry groceries and other products. Once elevators could be trusted, apartment buildings grew taller, and richer

tenants opted to enjoy the view from private penthouses while poorer ones were relegated to street-level apartments with all their noise and dirt. New York's seven-story Equitable Life Building, completed in 1870, was the first office building to utilize passenger elevators.

New York was also the site of the first buildings to showcase Otis's groundbreaking technology called "signal control," a system allowing the device to operate without human intervention. Signal control was introduced in 1924 in New York City's Standard Oil building. It allowed the doors to self-close, and passengers pressed keys for their desired floors, just as we do today.

Otis elevators, reliable because of their revolutionary safety brake, became a key component in the history of New York's iconic Empire State Building. When the structure was being constructed in 1931, Otis elevators made it possible for the building to reach its full height, including the observation deck on the 86th floor.

Company representatives still state that with the safety brake, elevator accidents are extremely rare. Many elevator accidents actually occur due to human error or negligence, as in 2011 when a New York City office worker was crushed to death when the elevator car surged upward with the door still open. The investigation showed that maintenance workers had disabled safety equipment during repairs and had neglected to reset the system.

Today, the Otis Elevator Company remains the largest maker of elevators in the world, providing and maintaining almost 2 million units in 200 countries around the globe. Otis elevators are in the world's tallest buildings, essentially making them possible. The company runs a 29-story testing tower at its research center in Connecticut. According to the corporation, its testers still use the words of the company's founder, Elisha Otis, when he confirmed that his revolutionary safety brakes had worked: "All safe."

Nancy Hendricks

See also Vol. 2, Sec. 1: Escalator

Further Reading

Bernard, Andreas. 2104. *Lifted: A Cultural History of the Elevator*. New York: NYU Press.

Goodwin, Jason. 2001. *Otis: Giving Rise to the Modern City*. Chicago: Ivan Dee.

Strakosch, George R., and Robert S. Caporale, eds. 2010. *The Vertical Transportation Handbook*. Hoboken, NJ: Wiley.

Equatorial Sextant

Sailors used compasses to navigate the world's oceans for centuries. Determining north could be just as tricky on water as it was on land. Sextants were invented in the 18th century to improve navigation, but like any mechanical device, they were only as accurate as the individual who used them. William Austin Burt (1792–1858) improved the accuracy of the compass in 1836 when he invented the solar compass, and 20 years later, he improved the accuracy of navigating the ocean with the equatorial sextant.

Burt's solar compass was one of the exhibits at the Great Exposition's Crystal Palace in London in 1851. Traditional compasses determined north by orienting to magnetic north, but their readings were not always accurate due to interference from large ore deposits and fluctuations in the earth's magnetic field. The solar compass did not have these problems. It determined north by orienting to the sun. Therefore, it was accurate in any location.

Burt's voyage from the United States to England to display the solar compass at the first World's Fair took weeks. The ship he traveled on went off course several times while crossing the Atlantic. Burt's round-trip voyage gave him an idea of how to adapt the sextant to plot ocean navigation more accurately.

The word "sextant" refers to a one-sixth arc of a circle, or 60 degrees. The sextant as a navigation tool is a handheld device with a 60-degree arc scale at the bottom. It has two mirrors, an adjustable arm, and a sight. The sight is a tube that resembles a small telescope. Facing the horizon, one looks through the sight at two mirrors. One mirror is half silver and half clear. The ocean horizon is viewed or sighted through the clear half of this mirror. Light from the object being sighted, the sun, reflects off the other mirror. This mirror is attached to a movable arm or lever. The moveable arm

is adjusted until the two images, horizon and sun, are in the same field of view. The reading on the scale is the angle between the sun and the horizon. This reading and the time of day of the observation (recorded in hours, minutes, and seconds) is then compared to a nautical reference chart. After solving some mathematical equations, one obtains the ship's latitude. Since the sun's angle of movement across the sky changes from season to season, calculations may have to be adjusted based on time of year. Sextants can be used at night. A star, such as Polaris, the North Star, is used for sighting.

Burt's sextant eliminated the need to consult a nautical chart. The equatorial sextant is an ordinary sextant with several adaptations attached. The main body or frame of the instrument is the meridian circle, which rotates on a spindle. All other measurement circles or arcs are directly or indirectly attached to this circle. There is a latitude circle, an hour circle, an azimuth circle, a declination arc, and an altitude arc. Azimuth, altitude, and declination determine a celestial body's location.

To use the equatorial sextant, the user sets a given latitude on the latitude circle. Then the declination arc is set as well as the time of observation. Without consulting any chart or completing a mathematical calculation, the user can read the altitude, azimuth, declination, latitude, and time on the sextant.

Burt received a U.S. patent in 1856 (patent number 16,002), and he patented the equatorial sextant in France, Belgium, and England in 1857.

This one device supplied the navigational information provided by a regular sextant and charts with no calculations required. Burt spent the last two years of his life promoting the equatorial sextant and died in 1858.

Linda Briley-Webb

See also Solar Compass; *Vol. 1, Sec. 2: Charting the Gulf Stream*

Further Reading

Burt, John S. 1985. *They Left Their Mark: William Austin Burt and His Sons, Surveyors of the Public Domain*. Rancho Cordova, CA: Landmark Enterprises.

Lanford, John, ed. 1997. *History of Astronomy: An Encyclopedia*. New York: Garland.

Field, Cyrus West (1819–1892)

Cyrus West Field, a successful American capitalist and financier, was instrumental in the laying of the first transatlantic telegraph cable. Field was born into a long-established New England Puritan family (with American roots perhaps as far back as 1629) in Stockbridge, Massachusetts, in 1819. Rather than pursue a higher education as did his three brothers—a well-known minister, a U.S. congressman, and a Supreme Court justice, respectively—Field joined the business world in his early teens. After trying his hand in a few different arenas, Field capitalized on new innovations in mass-market publishing and made a fortune in paper manufacturing. It would not be the last time an investment in new technology would pay him dividends. Because of his success, he was able to retire at age 34. After his retirement, Field focused his energies on philanthropy and investment, and he built a new career as a financier.

Throughout the 1830s and 1840s, a number of individuals had been developing electromagnetic technology that would create the telegraph. Samuel F. B. Morse's model was the most successful. After Morse invented his telegraph, though, he struggled to generate capital for laying cable. His line between Baltimore and Washington transmitted its first message in 1844, and soon, telegraph lines, laid by a number of competing companies, spread over the eastern United States and reached California by 1861. Despite much effort and multiple strategies, though, Morse had yet to accomplish the goal of connecting Europe and the United States via telegraph.

Field took an interest in this project. He invested his own money, and, even more important, he worked to secure funding from governmental and private sources as well as the services required for laying the cable. To these ends, Field partnered with Englishmen John Watkins Brett and Charles Tilston Bright to found the Atlantic Telegraph Company on November 6, 1856. They sold shares to investors and soon accumulated enough money to undertake the project.

The most significant obstacle preventing the linking of Europe and the United States, other than generating the money to do it, was a practical one. Laying cable over land was difficult enough, and the

process was developed only in fits and starts, but laying undersea cable was a tremendous feat of engineering. Bright was the leading engineer of the project, and he, Field, and others worked together to devise the best method for laying cables that would be protected, durable, and also, if possible, inexpensive. They also needed to find the most efficient route. There is a natural plateau between Newfoundland and Ireland where the ocean is shallower than in most parts, and here they decided to lay the cable. Also, Brett had already been involved in these plans, through the by-then-defunct Newfoundland Telegraph Company.

Beginning in 1857, the Atlantic Telegraph Company made several attempts to drop cables, the first three of which failed due to breakage. In 1858, a message was successfully sent across the ocean, but the cable was not sustainable and needed constant repairs. After three weeks, it was no longer operational. Field had some trouble generating more funds, especially from the U.S. federal government, given its involvement in the Civil War. In 1866, Field founded the Anglo-American Telegraph Company to recover some of the failed cables for repurposing and to lay new cable. That year's expedition, led by the steam ship *Great Eastern*, was finally successful.

Later in life, Field invested heavily in stocks, especially those of railroad companies. He increased his fortune and became a great patron of the arts, financing artists' endeavors and donating money and art to museums. However, toward the end of his life, he lost much of his money in futures speculation when the wheat market went under in the late 1880s. Field died on July 12, 1892.

Charles McCrary

See also Morse, Samuel F. B.; Morse Code; Telegraph; Transatlantic Cable

Further Reading

- Brown, Canter, Jr. 1989. "The International Ocean Telegraph." *The Florida Historical Quarterly* 68, no. 2 (October): 135–59.
- Carter, Samuel, III. 1968. *Cyrus Field: Man of Two Worlds*. New York: Putnam.



Cyrus West Field made his first fortune in the paper business. Later, he ambitiously invested in the construction of a communications cable across the Atlantic Ocean. (Library of Congress)

Gordon, John Steele. 2002. *A Thread Across the Ocean: The Heroic Story of the Transatlantic Cable*. New York: Walker.

Silverman, Kenneth. 2003. *Lightning Man: The Accursed Life of Samuel F. B. Morse*. New York: Knopf.

Fire Alarm Call Box

A fire alarm call box is a signaling apparatus designed for public use during fire emergencies. Call boxes are typically of cast iron and are mounted to utility poles or atop a pole. Modern call boxes have pull levers that can be directly operated by anyone, but earlier systems required a key holder to operate.

The fire alarm box was the creation of physician and inventor William Francis Channing (1820–1901) and electrical engineer Moses Gerrish Farmer (1820–1893). Channing was aware of Samuel Morse's (1791–1872) telegraph system and had the idea that it could be put to use as an alarm system.

Channing sold the idea of an alarm system to the city of Boston. On April 28, 1852, the first municipal fire alarm telegraph system was put into operation. It consisted of 40 call boxes and 16 alarm bells, all coordinated at a central Fire Alarm Office. To operate the alarm, a person had to open the box and turn a hand crank, which would send a telegraph signal to the central office that indicated the call box's location.

In 1855, South Carolina postmaster and telegraph company agent John Nelson Gamewell (1822–1896) was attending one of the frequent lectures presented by Channing on the fire alarm system. Gamewell was intrigued and purchased regional rights for marketing the system. On May 19, 1857, Channing and Farmer received a patent for their alarm system, and in 1859 Gamewell purchased all rights to the system.

During the Civil War, Gamewell returned to South Carolina. His patents were seized by the U.S. government and set to be auctioned off to the public. A company employee, John F. Kennard, was sent to Washington to bid on the patents and managed to win them back for only \$80.

In 1879, Gamewell reorganized his company, calling it the Gamewell Fire Alarm Telegraph Company. By the end of the century, Gamewell fire alarm systems were installed in more than 500 cities throughout the United States, including San Francisco (1865) and St. Paul, Minnesota (1873).

Because fire alarm call boxes are publicly available, they have often been abused for false alarms. A variety of remedies have been suggested for eliminating these, including a shed that locks behind a caller and a hare-brained approach that sprang a set of handcuffs on one.

Today, even with the ubiquitous cell phone, some cities have opted to keep their fire alarm boxes in use as part of a redundancy measure. The systems have proven themselves reliable during emergencies, and because the fire calls do not have to be routed through a dispatcher, there is no chance for language miscommunications.

Karen S. Garvin

See also Telegraph; *Vol. 1, Sec. 1: Fire Safety; Vol. 1, Sec. 2: Fire Hydrant; Vol. 3, Sec. 1: Smoke Detector*

Further Reading

- Ditzel, Paul. 1990. *Fire Alarm! The Fascinating Story Behind the Red Box on the Corner*. New Albany, IN: Fire Buff House.
- Greenburg, Amy. 1998. *Cause for Alarm: The Volunteer Fire Department in the Nineteenth-Century City*. Princeton, NJ: Princeton University Press.
- Hensler, Bruce. 2011. *Crucible of Fire: Nineteenth-Century Urban Fires and the Making of the Modern Fire Service*. Dulles, VA: Potomac Books.
- Tebeau, Mark. 2003. *Eating Smoke: Fire in Urban America, 1800–1950*. Baltimore: Johns Hopkins University Press.

Floating Dry Dock (1849)

Abraham Lincoln (1809–1865) accomplished many things in his lifetime. He was a self-taught man who worked a variety of manual labor jobs while studying in his free time. He loved books and learning, but he was very practical. If he encountered a problem, he solved it. One problem's solution led to an invention, and Lincoln is the only president of the United States to hold a U.S. patent, which he held for the invention of the floating dry dock.

Lincoln was born in Kentucky and grew up in Indiana. His family moved to Illinois in 1830. When Lincoln was a young man, he worked as a flatboat operator and hired hand on riverboats. A local businessman hired him to take merchandise from Sangamo Town, Illinois (north of Springfield), to market in New Orleans, Louisiana, in 1831. The water route was via the Sangamon River and the Illinois River to the Mississippi River.

Lincoln and another man loaded hogs and barrels of corn, bacon, and pork on a flatboat. The heavy boat ran aground on a milldam, with its front hanging over the dam while its back end slowly filled with water. Unable to force the boat over the dam, the men unloaded the hogs and cut a small hole in the bottom of the front part of the boat hanging over the dam. They moved some of the barrels to the front of the boat, and this redistribution of weight caused the boat to tip and the water to drain out the hole in the bottom.

The men plugged the hole, reloaded and redistributed the cargo, and the boat was able to float again.

Years later, Lincoln saw another boat grounded. That boat's crew used empty barrels to free it by forcing them under the boat's sides, which lifted it enough for them to move it. This method did not require taking cargo off the boat or redistributing it, and it gave Lincoln an idea. He invented a device that was fitted to the side of a boat just below the waterline on each side. It consisted of inflatable chambers, made of rubber cloth or similar waterproof material, that were attached to the boat. If a boat went aground, all or some of these chambers could be inflated using a bellows system or a steam engine. The inflated chamber(s) would lift the boat higher than what it was stuck on it could float freely again. When the chambers were no longer required, they would be deflated and repacked until needed.

Lincoln made a model of a boat with the device attached and applied for a patent. Though he was a lawyer, he hired patent attorneys to help process the application. The buoyancy device received patent number 6,469 in 1849.

The device was clever, but it had its drawbacks. One criticism was that other methods were available to free grounded boats, so the device was unnecessary. Another was that it would be expensive to install and

to maintain. Also, a lot of force was needed to inflate the chambers to raise a heavy boat over an obstruction. Plus, the chambers added weight to a boat and so might even cause the problem they were designed to fix.

A workable buoyancy device based on Lincoln's design was never produced, although his idea had merit. The idea of buoyant chambers was a precursor to those that engineers used when designing submarines. It was also similar to the process used by ship salvagers to refloat sunken vessels.

Lincoln was a man of many talents and is best remembered as president of the United States (1860–1865), member of Congress, a politician, and lawyer. Now inventor can be added to his list of accomplishments.

Linda Briley-Webb

See also *Vol. 1, Sec. 1*: Franklin, Benjamin; *Vol. 1, Sec. 2*: Jefferson, Thomas

Further Reading

Emerson, Jason. 2009. *Lincoln the Inventor*. Carbondale: Southern Illinois University Press.

Malkin, Michelle. 2015. *Who Built That: Awe-Inspiring Stories of American Tinkerpreneurs*. New York: Threshold Editions/Mercury Ink.

Primary Document: Excerpt from Abraham Lincoln's Patent Application for the Floating Dry Dock (1849)

In 1848, Abraham Lincoln traveled between congressional sessions from Washington to Illinois. Along the way, the flatboat he was traveling on was stuck on a sandbar. Lincoln watched as the crew used empty casks and boards to force the boat back into the water. This incident started him thinking about a floating dry dock apparatus that might be used to prevent just such a thing. His invention was never implemented, though he did have a scale model of it made. The following is an excerpt from Lincoln's patent application submitted by his patent attorney in March 1849. Lincoln was issued Patent No. 6,469 on May 22, 1849.

Be it known that I, Abraham Lincoln, of Springfield, in the county of Sangamon, in the state of Illinois, have invented a new and improved manner of combining adjustable buoyant air chambers with a steam boat or other vessel for the purpose of enabling their draught of water to be readily lessened to enable them to pass over bars, or through shallow water, without discharging their cargoes;

What I claim as my invention and desire to secure by letters patent is the combination of expansible buoyant chambers placed at the sides of a vessel with the main shaft or shafts C by means of the sliding

spars or shafts D which pass down through the buoyant chambers and are made fast to their bottoms and the series of ropes and pullies or their equivalents in such a manner that by turning the main shaft or shafts in one direction the buoyant chambers will be forced downwards into the water and at the same time expanded and filled with air for buoying up the

vessel by the displacement of water and by turning the shaft in an opposite direction the buoyant chambers will be contracted into a small space and secured against injury.

Source: Records of the Patent Office, Patented File, No. 6469.

Gas Well

Natural gas has come to dominate the American energy market, surpassing all other sources in recent years, and it all started with a single man in Fredonia, New York. For years, people had theorized, experimented, and told stories of natural gas that could be used for energy, but none of these were serious scientific or business inquiries. This all changed when an uneducated tinsmith named William Hart decided to take these stories and turn them into a commercial venture through the drilling of natural gas. While it is debated who first discovered natural gas, Hart was the first to successfully create natural gas wells and provide the energy directly to buyers.

In 1825, William Hart drilled his first gas wells in Fredonia, New York. The local paper originally reported that the drilling had been done in slate, but it was, in fact, in shale. Within months, the gas wells were providing the energy needed for lights in two shops, two stores, and a mill. The gas was stored in a gasometer, another Hart creation, and was transported to the shops through wooden pump-logs that were covered in tar-laden cloth at the joints. Hart's wells drilled into shale, which is a major source of natural gas. Gas in shale is accessed through fractures in the rock. These fractures allow gas to flow freely, which can then be collected and used as energy.

While the acquisition of natural gas first began with Hart, natural fractures had to be found to access the gas, which meant that there was very little available, making other energy sources, like coal, not only more practical but more profitable. With the profits of coal and later oil, natural gas remained a secondary source of energy

for much of American industrialization. The invention of hydraulic fracking changed the natural gas industry dramatically. With hydraulic fracking, more of the gas stored in shale could be accessed by creating artificial fractures that allowed the gas to flow. With both the technique of fracking and the discovery of vast natural gas deposits, the United States has become the world leader in natural gas production.

Energy production in the United States has shifted throughout history, but the legacy of Hart's business has survived with the renovated natural gas industry. Through recent discoveries, natural gas has become a main source of energy, especially in the United States. Hart's contributions to the energy industry were important both for his supply to a newly industrialized economy and through the creation of a new facet of American energy production. However, while natural gas might be a very profitable alternative to oil and coal, it is still a nonrenewable energy source. Fracking and natural gas might have helped ease financial problems with energy, but it is still a fossil fuel.

Damian Rodgers

See also *Vol. 1, Sec. 1: Street Lighting; Vol. 1, Sec. 2: Amphibious Steam Vehicle; Internal Combustion Engine; Vol. 3, Sec. 1: Hydraulic Fracturing ("Fracking")*

Further Reading

Smil, Vaclav. 2015. *Natural Gas: Fuel for the 21st Century*. New York: Wiley.

Smil, Vaclav. 2017. *Energy and Civilization: A History*. Cambridge, MA: MIT Press.

Gatling Gun. See Machine/Gatling Gun

Gold-Mining Technologies

Gold mining is the process of locating and extracting a pieces or shards of gold from the earth, typically via caves, deep pits, or mines. Since gold's discovery, many miners or searchers have used the technology of iron tools and makeshift wooden strainers to retrieve it.

There are three main factors that affect gold mining. These include exploration, mining, and placing. Exploration is the search for a possible location of gold. Mining is the bulk of the work, in which miners extract the gold from the ground. Last, nuggets of gold undergo a process called “placing” that separates them from the earth built up around the metal.

Evidence of gold mining can be found from as long ago as 4000 BC. Gold artifacts from the Bronze Age (3300–1200 BC) abound both in Europe and the Middle East. Bronze Age North American indigenous cultures also mined gold, particularly in areas of modern-day western Mexico and Colombia. Andean and Argentinian cultures also mined the metal.

The earliest gold mining in the United States took place in 1799 in North Carolina. While the western states are the most famous for gold mining, states as unlikely as Alabama and Florida have produced small amounts of gold. Large-scale gold mining did not begin in the United States until the discoveries in California in 1848. Known as the California Gold Rush, over 300,000 people migrated to California (which was not yet a state) in hopes of profit. A plethora of miners from all over the country and the world encouraged other economies as well, from agriculture to international trade. Boomtowns—some permanent, like Sacramento and San Francisco, and others impermanent—significantly expanded California's population.

While the Gold Rush made California an important state, it also had many negative effects. Mining causes significant environmental degradation. The Gold Rush also initiated the California Genocide wherein over 100,000 indigenous people died in the 20 years after 1848.

Gold-mining technology in the early 1800s consisted of general tools: shovels, picks, and pans used to extract the metal. The shovel was for digging deep in caves or in the ground; picks separated the embedded metal from the earth, and pans or bowls helped separate other particles from the gold. Water, or any other convenient liquid, was placed into the pans or bowls with the gold, helping separate it from any dirt.

Cradles were used when large amounts of gold were discovered. They resembled child's cradles but had screens at the bottom. Miners deposited large amounts of gravel, dirt, and sand in them and added water. Using a rocking movement, even the smallest pieces of gold could be recovered. This was the most effective and efficient tool for separating gold from anything attached to it.

Placer mining provided a bonanza of gold from riverbeds. Groups of prospectors or mining companies diverted water from them, exposing the river bottoms. This type of mining required considerable investment in equipment and time.

Some countries used other methods that did not include water. Arrastre was a form of dragging used to obtain gold. Powered mainly by horses and mules but sometimes water, a mill would drag large pieces of gold ore against stones to extract the metal.

By far the most environmentally destructive method of gold mining is hydraulic mining. Developed in 1853, hydraulic mining uses a high-pressure water hose to break down gold-bearing areas from hillsides to river beds. Loosened rock, gravel, and dirt are run through large sluices that function like elongated cradles. Gold collects at the bottom of the sluice while dirt and rock washes out. As for gold in rivers or canals, a hydraulic system was created to pump it out as miners scooped up gold and gravel and eventually placer the findings.

Gold was also mined in traditional, deep-earth mines. For example, the Elkhorn Mine in Montana often excavated gold, silver, and copper from the same mountain. Men from Wales and Ireland specialized in this type of mining, which was dangerous, low-wage work.

Chinese Americans worked in mines, often in auxiliary services like food production and

laundering, but also as gold miners of a sort. Areas with particularly rich gold sources would create rock waste, or tailings, that Chinese immigrants and others would remine. Anti-Chinese racism ran as high as anti-Native American racism in the American West.

Currently, gold-mining technology is far beyond the methods of simple iron tools. Such devices like metal detectors and drills have significantly advanced the search for gold. Gold remains one of the world's most sought-after metals as it is extremely valuable. Some mining methods, such as arrastre and the hydraulic method, are still used today. However, they have advanced—horses and mules no longer carry the burden of pushing the mill, because large machines now take care of this. As for hydraulic mining, the pressure in water is increased by applying jets to the pump.

The best place to discover gold today is South Africa.

Bhavesh Mukeshkumar Patel

See also Coal-Mining Technologies

Further Reading

Fetherling, Doug. 1997. *The Gold Crusades: A Social History of Gold Rushes, 1849–1929*. Toronto: University of Toronto Press.

Voynick, Stephen M. 1982. *In Search of Gold: Rock Mining, Planning, Treasure Hunting, Coin Beach-combing, Artifact Excavating*. Boulder, CO: Paladin Press.

Goodyear, Charles (1800–1860)

Charles Goodyear was born December 29, 1800, in New Haven, Connecticut. He is best known for discovering the process of vulcanizing rubber.

There was a “rubber fever” in the early 1830s, but it ended when no one seemed to be able to cure the problems of rubber freezing into a hard substance in the winter and melting into a smelly, gooey substance in the summer. Rubber factories went bankrupt in less than five years of opening.

Goodyear himself had been bankrupt when he first became seriously interested in rubber. He began working with natural rubber in 1834, when he was in a

Philadelphia debtor's prison. His wife brought him a batch of raw rubber, and he began experimenting relentlessly on it. He tried various products to absorb its stickiness. Nothing seemed to work well.

Goodyear moved his family to New York City, where he set up a laboratory in a friend's fourth-floor tenement bedroom. His brother-in-law lectured him about the sufferings he was putting his wife and children through, but Goodyear persisted in seeking a way to make rubber usable and profitable.

He made progress and even won a trade show prize for his work. However, his breakthrough came as the result of an accident—he applied nitric acid to remove bronze paint from a rubber sample, which turned black, and he tossed it in the garbage. But he remembered that the sample felt different from any others, so he retrieved it and noticed that it was smooth and dry.

This accidental success was enough for him to get backing from a New York businessman. The timing was not good. An economic depression wiped out the business, and Goodyear and his family, in poverty once more, moved into the abandoned factory, living on the fish he could catch. Eventually, Goodyear found other backers and manufactured 150 mailbags for the U.S. government. But the bags were left in a hot room and melted.

A happy accident again came to his rescue after five years of experiments and living off the charity of Massachusetts farmers in Woburn. In 1839, Goodyear was using a gum-and-sulfur formula. Angered by mockery from people in a store, Goodyear lost control of his rubber, and it flew onto a very hot potbellied stove—and it became weatherproof. More work had to be done to perfect his result. He needed to know how much heat to apply and for how long to the right amount of rubber.

After suffering many crises, including the loss of an infant child, Goodyear finally found the right combination of processes to vulcanize rubber. He also found a backer: his brother-in-law. Unfortunately, Goodyear divested himself of his manufacturing interests and went back to experimenting with rubber. He viewed it as a type of elastic, and indeed, many modern uses of rubber were first posited by him: rubber paint, rubber plastic for food packaging, car springs, ferryboat bumpers, and so on.

Although Goodyear had discovered how to vulcanize rubber, in England, Thomas Hancock patented such a process just before Goodyear did. Goodyear had salvaged his American patents thanks to the aid of Daniel Webster, but he was involved in a seemingly endless series of litigations in Europe. Unfortunately, Goodyear was not a good businessman and continued to lose money while others profited from his work. When he died in 1860, he was \$200,000 in debt—an enormous sum for that time. However, his patents eventually enabled his family to live in comfort. In 1898, after his death, the company was named after him.

Frank Salamone

See also Vulcanization

Further Reading

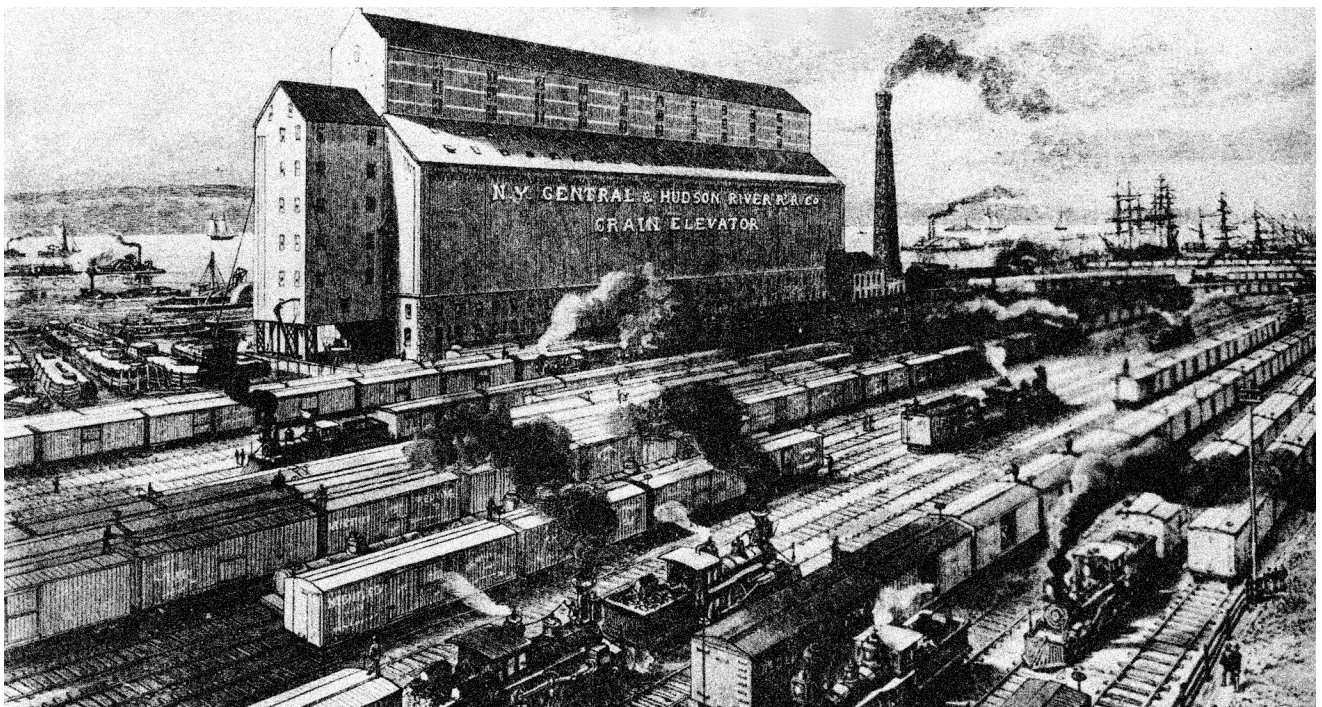
Slack, Charles. 2003. *Noble Obsession: Charles Goodyear, Thomas Hancock, and the Race to Unlock the Greatest Industrial Secret of the Nineteenth Century*. New York: Hyperion.

Travers, Bridget, ed. 1994. *World of Invention*. Detroit: Gale Research.

Grain Elevator

Grain elevators served to keep crops safe and preserved while in transport beginning with their invention in 1842 by Joseph Dart. Grain crops are an essential ingredient in many of the foods we eat today, but it would not be until the 1800s that grains became mass-produced. Most American grain production has involved the Midwest region of the United States. Some other areas could only use such crops if they were transported to them, which was a rather difficult task at the time.

The transportation of grain to the East would become easier with the construction of the Erie Canal, established in the year 1825. The canal proved successful and raised the status and importance of the city of Buffalo, but it raised another issue. The amount of grain being shipped, along with the size of the ships used to do it, prevented further travel on certain waterways. Grain had to be unloaded and then reloaded onto smaller boats that would fit on the canal. This process took as long as a few days to as much as a week. Joseph Dart noted this dilemma and thus created what is now known as the grain elevator.



Grain elevators dominate a freight yard in New York City, ca. 1890. Such elevators played a crucial role in the transport of grains during the early years of expanding railway systems. (Three Lions/Getty Images)

Born in 1799, Dart had made his way to Buffalo at 21 years of age to pursue a partnership with merchant Joseph Stockholm. Their short-lived partnership led Dart to the grain trade. The canal carried heavy traffic, and when not all of a ship's grain could be loaded onto a smaller boat, it still all had to be unloaded from the larger one. Again, such a process would take a whole crew of stevedores days or even weeks to complete. It could take much longer if the weather was inclement. Dart observed that the process cost travelers time.

To address the problem, Dart hired Robert Dunbar, an engineer with prior experience with mill projects, who helped him create the grain elevator in 1842. The elevator took inspiration from the steam-powered flour mills that Oliver Evans had invented many years before. For example, Dart borrowed the idea of the conveyor belt for his own mechanism. It would also be steam powered—and constructed out of wood due to the supply available in the city of Buffalo.

The stevedores, however, who were mostly Irish immigrants, did not favor the invention, as it was intended to do their job faster and more efficiently, eventually leaving them out of work. Many doubted the elevator would even function. But Dart's grain elevator accomplished what it set out to do and more: it significantly cut the time needed to unload ships and acted as storage for whatever grain was left behind to be picked up later by local merchants. What used to take a week now took a mere few hours. The *Philadelphia* was the first ship to be unloaded mechanically with the use of Dart's elevator. The grain was directly taken from the ship and lifted into the storage bins on-site. It did not take much longer for Buffalo to see another elevator built, and it started a chain of more elevators. By 1848, at least six elevators operated along the Buffalo River, quickly rising to a count of 20 by 1860.

Dannela Azul Valencia

See also *Vol. 1, Sec. 2*: Erie Canal; Evans, Oliver; High-Pressure Steam Engine

Further Reading

Baxter, Henry H. 1980. *Grain Elevators*. Vol. 26. Buffalo, NY: Buffalo and Erie County Historical Society.

Brown, William J. 2009. *American Colossus: The Grain Elevator, 1843 to 1943*. Morrisville, NC: Lulu Press.

"Grain Elevators Invented in 1842." *AgHires*. <https://ag hires.com/grain-elevators-invented-1842/>, accessed August 22, 2018.

Schwarzmueller, Anton. 2015. "The Engineers of the Grain Elevators." *Historical Marker Database*, July 13. <https://www.hmdb.org/marker.asp?marker=85435>, accessed August 22, 2018.

Gridiron for Cooking

A gridiron is a frame of parallel bars or beams that are typically in two sets arranged at right angles, to be used as a cooking grill. It is used over an open flame and can be used to cook a variety of foods. Many gridirons were made and patented in the United States in the 1800s, and over time, many have been developed specifically for different types of food. A combination hinged gridiron was developed and patented by Amasa and George Sizer in 1836. The steel wire gridiron was patented by William C. Perkins in 1889; it would hold meat in place for broiling.

Today, gridirons are used to broil food especially in fast-food restaurants. Gridirons come in different shapes and sizes depending on the use. Usually, they are a square or rectangular, but they also can be circular or oval. Gridirons are usually made with iron or cast iron, but any other metal that is suitable for cooking may also be used.

Hannah Reutershan

See also Compact Iron Stove

Further Reading

Cookbook Committee. 1996. *Gridiron Gourmet*. Waverly, IA: G & R.

Hand-Cranked Ice Cream Maker

Ice cream is a dessert that one consumes to satisfy a sweet tooth as well as a way to treat oneself in hot weather. Today, there are many flavors and sizes to

choose from—options that were uncommon many years ago. And ice cream is now considered one of the most common and affordable sweet treats, unlike in the past, when it was associated with the wealthy and those of higher status because of its labor-intensive and time-consuming preparation. Nancy M. Johnson invented the mechanism that made it easier for more people to have ice cream.

Ice cream was not introduced to America until the mid-1700s by Governor Blandon of Maryland. In that era, its ingredients were either not readily available or rather expensive. Ice, for example, was only available to those who had access to frozen lakes and ponds, and once collected, it had to be stored in insulated chambers.

The most common process used to make ice cream leading up to the mid-1800s, the “pot freezer” method, called for two pots of different sizes, each filled with different ingredients. The larger was filled with ice and salt and the smaller with cream, sugar, and a flavoring. The mixture had to be stirred frequently to prevent the formation of large crystals, which caused a dense consistency. Such a process could take up to an hour before the ice cream was ready. Johnson came up with a solution that cut down the time and made things much easier for those who wanted to make ice cream themselves.

Johnson received a patent on September 9, 1843, for her hand-cranked ice cream machine. Her mechanism applied the same idea of the “pot freezer” method but with an improved approach. Her machine used a wooden bucket for the ice and salt, and it also held a metal container filled with the ice cream mixture. The metal container was covered with a lid that had a built-in paddle connected to the crank, and the moving parts worked simultaneously. The paddle made all the difference. As the crank operated, it scraped layers of material from the inside of the tin container, preventing larger crystals from forming within the mixture and allowing a much smoother consistency. With Johnson’s invention, the time to make the dessert was cut to half an hour.

Despite it being a 170-year-old method, ice cream is still made today using Johnson’s innovation.

Dannela Azul Valencia

See also *Vol. 2, Sec. 1: Ice Cream Soda*

Further Reading

- Kraft, Amy. 2014. “Here’s How Ice Cream Was Made in the 1800s—Modern Notion.” *Modern Notion*, July 10. <http://modernnotion.com/heres-ice-cream-made-1800s/>, accessed August 22, 2018.
- “Legends and Myths of Ices and Ice Cream History.” 2015. *What’s Cooking America*, May 14. <https://whatscookingamerica.net/History/IceCream/IceCreamHistory.htm>, accessed August 22, 2018.
- Schwarcz, Joe. 2001. “Agitate, Agitate for Ice Cream.” *The Gazette*, June 3. <http://www.montrealgazette.com/columnists/joe-schwarcz.html>, accessed August 22, 2018.

Health Reform

During the antebellum period, health reform developed as a challenge to traditional medical practices. Until the 19th century, the study of medicine had been based on the belief that the body was made up of vital forces or humors. Mostly male doctors sought to remedy this imbalance with bloodletting, enemas, lancing boils, or by inducing vomiting. Following the reform impulse of the Second Great Awakening (1790–1840), however, social reformers, many of them women, promoted alternative means to achieving health, including vegetarianism, exercise, and daily bathing. This widespread movement for health reform took the responsibility of good health out of the hands of doctors and placed it in the hands of ordinary men and women.

Beginning in the presidency of Andrew Jackson (1829–1837), the United States experienced a period of urbanization and industrialization. Evangelicals argued that society was suffering from moral downfall as the result of economic development and the expansion of cities. Consequently, reform movements directed at perfecting society were established, including antislavery, women’s rights, temperance, education, dress reform, and health reform.

Until approximately 1830, medical practices in the United States had been based on the ancient concept that health depended on the alignment of vital forces or humors. When one of these humors became imbalanced in the body, a person became ill. Medical

doctors believed that excess fluid must be released to restore the humors. Doctors' practice of bleeding patients for tuberculosis or women recovering from childbirth killed uncounted women, though the medical profession had difficulty realizing that its practices harmed more patients than it helped.

The health reform movement first gained support in New England, where sectarian medicine replaced some orthodox medicine. Sectarian medicine differed from traditional medicine by promoting daily bathing, limited diet, and moderation in sex, exercise, athletics, and fresh air rather than violent purging or bloodletting. These practices were especially appealing to women, because they fell under the realm of the home and its management.

According to antebellum practices, women's proper place was within the private sphere of the home, and their roles revolved around domesticity. Women were also thought to be naturally more moral than men and therefore closer to God, a belief emphasized during the Second Great Awakening. This meant that it was a woman's responsibility not only to uphold the home but to maintain the health and morality of the family through personal action and child rearing. Health reform specifically appealed to women because it placed the responsibility of health in the hands of the individual and promised to target illness and sin. Health reform promoted noninvasive cures for physical maladies from which women suffered, including physical weakness, menstrual distress, and nervous disorders. Industrialization also contributed to women's interest in health reform because, with more factory-produced goods available, the need for home production decreased. As a result, women found themselves with free time to dedicate to the preservation of their homes and specifically to their own health and the health of their families.

Among the most famous health reform leaders was Sylvester Graham (1794–1851). Graham, along with his fellow advocate for vegetarianism William Andrus Alcott (1798–1859), argued that illness could be cured with diet and exercise. He promoted vegetarianism and invented the Graham cracker, which he argued was healthier than purchased bread that had chemical additives. Graham had begun as a temperance reformer, which led him to conclude that gluttony

in food as well as drink was unhealthy. In 1830, Graham also began lecturing on the merits of daily baths. Graham disciples Mary Grove Nichols (1810–1884) and Paulina Wright Davis (1813–1876) also advocated for vegetarianism and improved hygiene. Nichols and Davis joined the lecture circuit and traveled around the country speaking about the benefits of health reform.

Hydropathy is perhaps one of the most well-known divisions of health reform. Popularly known as the “water cure,” hydropathy appealed to both men and women and promoted the consumption and use of water to cure illness. In addition to drinking and bathing in fresh water, hydropaths encouraged douches, wrapping patients in wet sheets, and submerging them in water. Combined with fresh air, exercise, healthy diet, and limited sex, hydropathy promised to cure any ailment. Hydropathic practices could be applied at home, which made it accessible to all classes, but spas where room and board could be obtained for a fee were popular with the upper and middle classes. Hydropathy specifically targeted female patients because it proposed to cure complaints related to nervous conditions, menstruation, and childbirth. Health reformers also targeted women's fashion as one cause of illness, because they claimed that corsets constricted organs and that long skirts spread disease by catching trash as women walked through the streets.

For women, hydropathy also offered opportunities to practice medicine that were unavailable elsewhere. In 1851, Mary Grove Nichols and her husband, Thomas Low Nichols, opened the American Hydropathic Institute. Hydropathic doctor Joel Shew (1816–1855) and his wife, Mary Louise Shew, promoted the water cure as part of midwifery. Harriet N. Austin (1825–1891) worked as a water cure physician, writer, and health reformer, and Rachel Gleason (1820–1905), along with her husband, Silas Gleason (1818–1899), made women's health their water cure specialty.

Health reformers also influenced other groups to adopt health reform. During the 1860s, Seventh Day Adventists, under the guidance of Ellen White (1827–1915), adopted vegetarianism and diets with simple foods. John Harvey Kellogg (1852–1943), creator of the cornflake, was a holistic doctor who promoted vegetarianism, exercise, and enemas.

Laura J. Ping

See also Corset; *Vol. 2, Sec. 1*: National Institutes of Health (NIH)

Further Reading

- Cayleff, Susan E. 1987. *Wash and Be Healed: The Water Cure Movement and Women's Health*. Philadelphia: Temple University Press.
- Donegan, Jane B. 1986. *"Hydropathic Highway to Health": Women and Water-Cure in Antebellum America*. New York: Greenwood Press.
- Sokolow, Jayme A. 1983. *Eros and Modernization: Sylvester Graham, Health Reform, and the Origins of Victorian Sexuality in America*. Hackensack, NJ: Fairleigh Dickinson University Press.
- Whorton, James. 1982. *Crusaders for Fitness: The History of American Health Reformers*. Princeton, NJ: Princeton University Press.

Henry, Joseph (1797–1878)

Joseph Henry was a 19th-century American scientist who made important discoveries in magnetism and electricity. His scientific work and his skill as a promoter of science were recognized when he was chosen as the first secretary of the Smithsonian Institution.

Born in Albany, New York, in 1797, Henry moved to the small town of Galway, New York, as a child following his father's death. There, he began to study science and won a scholarship to the Albany Academy, a prestigious preparatory school. His academic performance won him a teaching position at the school in 1828. He took several years to finish his studies because the growth of his family prompted him to take work as a surveyor.

While teaching at the Albany Academy, Henry began conducting experiments on electromagnetism. He made a number of important discoveries, including a method of strengthening electromagnets to allow the transmission of current over long distances. This discovery underpinned all later research on electric motors and power transmission. To demonstrate his discoveries, Henry unveiled a prototype telegraph. Not realizing the commercial potential of his work, Henry failed to patent it—and after early encouragement, he broke off a burgeoning friendship with Samuel Morse

when Morse tried to patent and commercialize his own telegraph. The scientific value of Henry's work became truly apparent only years later; the property of inductance he revealed showed that changing the current through a material conducting electricity created a magnetic field. Independently discovered by the British physicist Michael Faraday, this principle is at the heart of all modern research in electronics.

As a result of Henry's work and his reputation as an excellent teacher, he was hired in 1832 as a professor of natural philosophy at the College of New Jersey, now Princeton University. He continued to publish on electromagnetism and other subjects (including astronomy, optics, and acoustics), building an increasingly strong reputation. In 1837, he toured Europe and established relationships with a number of prestigious scientists there.

In 1840, Henry was elected to help manage a collection of artifacts returned to Washington, D.C., by the U.S. Exploring Expedition of 1838–1842. Concerns over the preservation of this collection helped spark interest in establishing a national museum. This led to the establishment of the Smithsonian Institution. In 1846, the board of regents for the new Smithsonian Institution offered Henry the role of secretary, close in practice to the modern title of chief executive officer. He made the difficult decision to leave Princeton and uproot his family, arriving in Washington, D.C., in 1847. While Henry detested the climate of Washington and was absent most summers, he threw himself quickly into his work. Shortly after arriving, he focused the Smithsonian on the support of scientific research in a number of fields. He donated the Smithsonian's book collection to the Library of Congress and launched a scientific journal in 1848.

Henry worked tirelessly to establish a true scientific community in the United States. He provided grants to promising researchers, encouraged a network of volunteers to provide meteorological data, and established an international exchange to distribute scientific papers across the world. His meteorology network became the basis of scientific weather forecasting. In 1852, he was appointed to the U.S. Light-House Board. As a board member and later chairman, Henry had influence over a large research budget—16 times that available to the Smithsonian.

During the Civil War, Henry advised the military on aerial observation (the use of hot air balloons in military espionage and battlefield strategy planning) and other new technologies. In 1863, he helped found the National Academy of the Sciences, an organization that is still powerful today. He continued as the secretary of the Smithsonian, as a board member for the National Academy of the Sciences, and as an active board member and researcher for the National Light-House Board for years. He suffered a stroke in December 1877 and died in April 1878. One of his last acts was to advise and encourage Alexander Graham Bell as he developed the first prototype telephone.

James L. Erwin

See also Coil Magnet/Electromagnet; Electric Doorbell; *Vol. 1, Sec. 1*: Franklin, Benjamin

Further Reading

Moyer, Albert E. 1997. *Joseph Henry: The Rise of an American Scientist*. Washington, D.C.: Smithsonian Institution Scholarly Press.

Hoop Skirt

A hoop skirt is a garment worn under a woman's skirt or dress that is designed to flare it out. Once the hoop apparatus is fashioned around the wearer's waist, the clothing is placed over the hoops, encircling the wearer in fabric and creating some type of bell shape, depending on the era, to the woman's silhouette. The desired effect is to create aesthetic appeal to the opposite sex with full hips and slender waist. Variations of this fashion garment have been worn for almost three centuries. Desire for the popular undergarment fueled booming technological advancements in shipping and later the steel industry, spanning multiple continents.

During the European Renaissance era (12th to 15th centuries), the Spanish, French, and later the English manufactured this undergarment, then referred to as a farthingale. Made from whalebone bent into circles of graduating sizes that were sewn onto linen fabric that was belted around the waist, the hoops would be placed over petticoats or crinoline undergarments and then cinched at the waist of the wearer,

accentuating the figure. As noted, this was to create the illusion of a slender waist by augmenting the hips.

Variations of this garment continued to appear throughout Europe and America. Examples included "panniers," which were hoops worn exclusively over the hips, during the 1680s–1750s. These kept the front and back of a dress flattened to the wearer's body, flaring out only its sides. The hoop petticoat, cage crinoline, or cage petticoat had hoops made from wire, whalebone, or cane sewn into a petticoat (steel was used after 1857) that widely encircled the wearer during the 1860s.

The labor-intensive making of these garments, plus the cost of materials and the fact that they restricted movement, meant that only very wealthy women used them. With the advent of the Industrial Revolution, or "crinoline period" in America—and the invention of the sewing machine—factory production of hoops increased; the cost therefore decreased, so the product could reach a greater audience of women of all social classes who, like their more affluent sisters, could now avail themselves of the latest in fashion.

As demand grew greater, industries sprang up to keep up with the cyclical fashion industry. Europe in the 1700s witnessed an increase in whaling and, as an offshoot, in shipbuilding to keep up with orders that included bustles and crinolines. Later on, steel manufacturing increased to meet the increased demand for new fashion devices. Ultimately, this drove costs down.

Fashion styles came from Europe and France, emulating those of the upper classes and royalty during the colonial period and on up to the 20th century. American women copied European fashions infused with their own aesthetic; skirts and dresses were heavily draped in layers of rich fabric and flared out (as much as 15 feet in diameter) with the aid of hoops. Hoop skirts achieved the most prominence during the antebellum period in 19th-century America, typically in the Southern states. The modern predecessor of the hoop skirt was inspired by the architectural style of the Crystal Palace in England from 1851. Patents were issued (often for women) for variations and improvements on hoop designs, so popular was the undergarment.

The first wave of American feminists found 19th-century women's excessive clothing confining, inhibiting even simple movements. Surviving letters from women migrating to the American frontier wrote that some women chose to wear their hoops despite their

impracticality amid the rigors of overland travel. Whether by covered wagon or travel by train, the cumbersome nature of the hoop skirt did not lend itself to any practical uses and, indeed, it only added to an already difficult journey. Letters record people witnessing Native Americans wearing European style clothing.

During the American Civil War (1861–1865), hoop skirts realized a practical and rather creative function, joining the war effort as vehicles for smuggling contraband to husbands, fathers, and brothers into enemy territory. Records from the era record that the skirts could conceal food, ammunition, and clothing and even enterprising men wishing to end their participation in the war, carefully hidden in the folds of material enveloping the hoop skirt. By the end of the Civil War, hoop skirts were discarded in favor of simpler dress styles, reflecting a changing society.

Cynthia J. Parker

See also Sewing Machine, Automated; Sewing Pattern

Further Reading

Hennessy, Kathryn, ed. 2012. *Fashion: The Definitive History of Costume and Style*. New York: DK.

Tortora, Phyllis G., and Keith Eubank. 2004. *Survey of Historic Costume*. 3rd ed. New York: Fairchild.

Willett, C., and Phillis Cunningham. 1992. *The History of Underclothes*. 2nd ed. New York: Dover.

Horse-Drawn Streetcar

Also known as a horse car or horse-drawn tram, horse-drawn streetcars were designed and patented in the 1830s by John Stephenson, who also designed and created the New York and Harlem railway in November 1832. John Stephenson is credited with creating the first modern tramway.

Stephenson was born in 1809 in Ireland and migrated to the United States with his family when he was two years old. He attended public school in New York City and finished his education at Wesleyan University in Connecticut. In May of 1831, he created his own business, known as John Stephenson Company, and was greeted by a series of both breakthroughs and misfortunes. Originally, Stephenson designed omnibuses: large, horse-drawn carriage buses. In the early 1830s

John Mason, a powerful merchant and banker, paid Stephenson to develop a horse car for the newly created New York and Harlem railway, an early urban streetcar system. Stephenson developed the first streetcars for Mason's company and patented his design in 1833.

Stephenson suffered a bankruptcy in 1842 when his business finally collapsed after years of financial issues created by "the panic of 1837," when bonds he had accepted had become virtually worthless. However, his spirit could not be broken. Each time he experienced a setback, he picked himself up and moved on. In 1843, he reopened his business and was met with incredible success. For years, his company was the dominant manufacturer of streetcars. It is estimated that his firm created 25,000 of them between 1876 and 1891 alone. When he passed in 1893, his factory was producing 25 cars a week and had hired 500 employees to meet that goal. The story of John Stephenson is a tale that represents human willpower and the ability to persevere. Even though there were countless deterrents in his life, Stephenson refused to yield. It is because of this action that John Stephenson was able to completely change how public transport operated and how society views public transport.

Horse-drawn streetcars are similar to modern trolleys except that they are moved by actual horsepower rather than electricity. This mode of transportation was more efficient and essentially the precursor to buses and bus routes, as they followed a set path and arrived at each destination within an allotted amount of time. The grooves in the railway that trams were attached to allowed the horses to pull a heavier load much more easily, and the riding experience was less turbulent.

Initially, horse-drawn streetcars were pulled by four horses each and were capable of carrying up to 30 passengers in their compartments. By cutting the weight of the streetcars in half—from 6,800 to 3,500 pounds—Stephenson's cars could use two horses to pull rather than four. This meant that more streetcars could run at once. Fewer horses also meant less horse manure—which caused immense public health problems. Stephenson accomplished the drastic decrease in weight by building the carriages with woods like hickory instead of oak. He also modified the structure, removing doors and simplifying passenger accommodations. Stephenson continuously sought to improve upon his

initial design and was documented as filing at least 11 patents in the process.

Peg A. Lamphier

See also Electric Street Railway; Railroad T-Rail and Tie; Railroads; *Vol. 1, Sec. 2: Steam Engine*

Further Reading

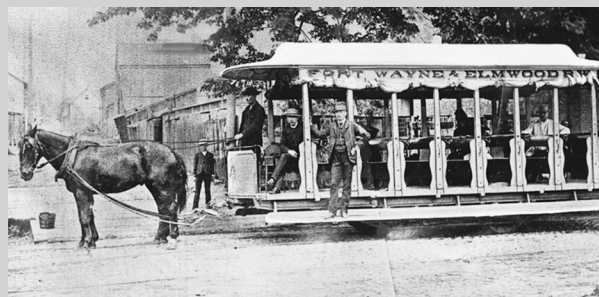
Hepp, John H. 2008. "The Horse in the City: Living Machines in the Nineteenth Century." *The American Historical Review* 113, no. 3: 844.

Hornung, Clarence Pearson. 1959. *Wheels Across America: A Pictorial Cavalcade Illustrating the Early Development of Vehicular Transportation*. New York: A. S. Barnes.

"Sanitary Conditions of Street Cars." 1902. *JAMA: The Journal of the American Medical Association* XXXVII, no. 22: 1449.

Primary Document: Image of a Horse-Drawn Streetcar (c. 1920)

This photo of a horse-drawn streetcar, probably in Detroit, dates to around 1920.



Source: Library of Congress.

Hospital Transport Service, Women's Department

Established in the early days of the American Civil War by Frederick Law Olmsted, the purpose of the Hospital Transport Service (HTS) of the U.S. Sanitary Commission was to charter, supply, and maintain a fleet of riverboats to use as floating ambulances as

well as floating hospitals. The HTS served the Union Army and employed countless numbers of female nurses in its Women's Department.

The U.S. Sanitary Commission itself, a civilian organization, was created on June 9, 1861, and was given the authority, in cooperation with the Union medical department, to establish medical guidelines in the field, inspect medical facilities of the military, and provide medical supplies as needed. To this end, the HTS pressed or leased into service a fleet of ships of various shapes and sizes, including paddleboats and steamboats. The HTS operated in both the Eastern and the Western Theaters of the war, particularly on the Virginia and Mississippi Rivers. In many cases, wounded and sick soldiers were transported to the hospital ships to either be tended to where medical facilities lacked on the shore or to evacuate and triage soldiers who then were brought farther north, behind Union lines. In the Eastern Theater, many of the hospital ships transported soldiers to large cities for further treatment and convalescence, including such northern locations as Washington, Philadelphia, and New York. The HTS employed a variety of ships for use in the Union medical system, including the *City of Memphis*, the *Daniel Webster*, the *Red Rover*, the *Wilson Small*, the *Knickerbocker*, and the *Elm City*. By the end of its service, the HTS employed more than a dozen hospital ships serving in the various theaters of the war.

At the start of the war, civilians and political leaders in the Union, and much more prominently in the Confederacy, heatedly debated the role of women not only in the medical services but also in the military. Women faced opposition by both civilian and military organizations based on the view that war and medicine were not proper spheres of activity for respectable ladies. Also, many Americans believed that the constant close proximity of women to male bodies, bodily fluids, and disease would compromise female honor and virtue. But as the war continued to rage over the years, attitudes toward the presence of women in the medical services shifted as women proved themselves. During and after the war, society came to view nursing as an extension of a woman's "natural" role as caregiver. Thus, the HTS and the U.S. Sanitary Commission played important and active parts in redefining

gender roles in warfare and Northern society during the 19th century.

During the opening days of the Civil War, many of the white, upper- and middle-class female volunteers accompanied their husbands or other family members into military service in the hopes that they might both serve their country and stay close to their loved ones. These women rarely possessed any formal medical education and were, in many cases, viewed as nuisances by the Union Army. Along with these women, both Catholic nuns and escaped female slaves volunteered to aid the military in its fledgling medical system. Harriet Tubman, for example, did some nursing during the war, though she primarily served as a spy and scout for the Union Army.

In the beginning, the primary role for white, female volunteers was to supervise the freed slave men and women and the convalescent soldiers who worked as servants and orderlies on the hospital ships. However, as the war progressed and the number of sick and wounded soldiers began to overwhelm the Union medical staff, these volunteers began taking a more active role in the medical care of wounded soldiers.

These women became more involved in the daily planning and provision of necessary medical care for the soldiers on board the hospital ships. Many of their daily tasks included assisting the army medical staff with operations and treatment, supplying patients with medicine, tending to the nutritional needs of the soldiers, and cleaning and restocking the ships for new patients during the return trips to the front. According to Civil War statistics, approximately 3,200 Northern women, mostly white, middle-class volunteers, served in the Hospital Transport Services and the United States Sanitary Commission during the course of the American Civil War, when the hospital ships carried approximately 10,000 wounded or sick soldiers from the battlefield to safety behind the lines.

The Hospital Transport Services' influence began to decline by late 1862 and early 1863, particularly as the wartime action moved farther away from the major rivers and toward the interior of the Confederacy. Along with the relocation of the battlefronts during the war, the Services also began to decline due to the appointment of Jonathan Letterman to the position of medical director of the Army of the Potomac. In his

post, Letterman reorganized the Union medical system to create a highly effective ambulance service, making the civilian-run Hospital Transport Services obsolete—though not the hospital ships. By the summer of 1862, Olmsted recommended to Letterman that all of the medical transportation services, both military and civilian, be consolidated under the Medical Bureau and the hospital ships be transferred to the jurisdiction of the quartermaster department. The United States Sanitary Commission continued to support the Union Army in the war effort until it was disbanded in July 1865.

Chelsea Medlock

See also Civil War Nursing; Dix, Dorothea

Further Reading

- Giesburg, Judith Ann. 2006. *Civil War Sisterhood: The U.S. Sanitary Commission and Women's Politics in Transition*. Boston: Northeastern University Press.
- Rybczynski, Witold. 1999. *A Clearing in the Distance: Frederick Law Olmsted and America in the Nineteenth Century*. New York: Scribner.
- Schultz, Jane. 2007. *Women at the Front: Hospital Workers in Civil War America*. Chapel Hill: University of North Carolina Press.

Howe, Elias (1819–1867)

Elias Howe Jr. of Spencer, Massachusetts, invented the sewing machine. Howe belonged to a poor family and struggled to overcome poverty while working to create his invention. Passionate about machinery and inventing, Howe sought to relieve women and children of the burdens of hand sewing. He had watched his family struggle to mill cotton and had desired as a young child to free them of this laborious job. Before the creation of the sewing machine, women and children worked in textile mills, sewing clothing, shoes, and other materials together by hand. Conditions inside the mills were dangerous and burdensome. Although society initially rejected the sewing machine, Howe's invention changed the course of labor for women forever.

Born in 1819, in Spencer, Massachusetts, Elias Howe Jr. was the son of a cotton farmer and miller.



Elias Howe invented an efficient sewing machine in 1845, which revolutionized the country's industrial sector and changed life for countless homemakers. It was the first product of the Industrial Revolution targeted at the female consumer. (Metropolitan Museum of Art)

Like most farming families, the Howe family was large, with eight children. From a young age, Elias Howe had worked alongside his brothers and sisters on the farm to clean cotton and prep it for sale in a process called “carding.” With a desire to be independent and help his family, Howe eventually left home to work at a machine shop in Cambridge, Massachusetts. Howe was a quick learner, mastering the machinery with ease—such as spinning machines and power looms—due to his apprenticeship experience at Lowell cotton mills.

In 1841, Elias Howe moved to Boston after marrying Elizabeth Jennings Ames. The couple had three children: Jane Robinson Howe, Simon Ames Howe, and Julia Marie Howe. Originally, Howe struggled to create his invention because he lacked funding to purchase or make parts. But an English investor helped him to complete the sewing machine in May 1844. Howe patented it 1845 and immediately began improving his

design when he realized that others had stolen his idea. In 1854, after establishing his rights to the machine, Howe's fortune grew as manufacturers started purchasing it. The needles on his machines had the eye at the point, an automatic feed, and a lockstitch function.

Elias Howe died at age 48 in 1867. Although he only enjoyed success for a short time, Howe remains an influential mechanical engineer whose project enabled the mass production of clothing and brought progress to the textile industry. Howe's design for the sewing machine laid the foundation for all modern sewing machines.

Katrina Boggus

See also Vol. 1, Sec. 2: Lowell Mill System

Further Reading

Hubert, Phillip G. 2000. *Men of Achievement: Inventors*. Scituate, MA: Digital Scanning.

Parkman, Mary Rosetta. 1921. *Conquests of Invention: Cyrus H. McCormick, Elias Howe, Thomas A. Edison, William Murdock, Robert Fulton, Guglielmo Marconi, Charles Goodyear, George Westinghouse, Eli Whitney, Alexander Graham Bell*. New York: The Century Company.

Howe Truss

Patented by William Howe in 1840, the Howe truss was an innovation in civil engineering and public transportation. The Howe truss bridge belongs to the family of truss bridges because it employs a structure formed by constructing triangular shapes that enable the bridge to support heavy weight. The Howe truss design incorporates horizontal pieces that enclose diagonally and vertically placed pieces in the middle. Built of wood and iron, the bridge became popular because of its durability and strength.

William Howe, a farmer in the rural town of Spencer, Massachusetts, was the descendant of the inventor Elias Howe. The Boston and Albany Railroad company contracted Howe to build a railroad bridge over the Connecticut River in Springfield, Massachusetts, because he was a talented inventor and bridge engineer. Howe developed the Howe truss bridge after studying truss bridge structure and improving the quality of other truss bridges.

The Howe truss consists of vertical iron pieces attached to wooden diagonal pieces. Typically, the wooden parts were of white oak, cedar, pine, fir, or hemlock. The iron pieces made the truss bridge stronger and more durable, able to support heavy trains. Wood and iron together enable the bridge to resist tension. The diagonal support beams slope upward and toward the middle, which redirects compression to the top of the bridge. The bridge components endure force individually so that each member can safely support its proportion of weight.

By using iron, the Howe truss bridge could extend across greater distances, such as canyons and riverbeds. Iron also eliminated some of the weight of traditional wooden panels. For this reason, Howe's design became popular among 19th- and early 20th-century engineers because of its simplicity: it made construction easier and faster. Once the Howe truss became popular in the United States, other countries, such as Russia and Germany, began to use the design.

The Howe truss improved public transportation and the transportation of goods because it improved the safety of train travel. The design of the Howe truss also enabled goods to travel farther.

Katrina Boggus

See also Howe, Elias

Further Reading

American Society of Civil Engineers. 1959. *American Wooden Bridges*. New York: ASCE.

Edwards, Llewellyn. 1959. *A Record of History and Evolution of Early American Bridges*. Orono, ME: Maine University Press.

Steinman, David, and Sara Ruth Watson. 1957. *Bridges and Their Builders*. New York: Dover.

Hunt, Walter. See Safety Pin

Interchangeable Gun Parts

Firearms manufactured before 1700 were made by hand. Each gun was one of a kind and expensive. If a part broke, the gun was sent to a gunsmith to determine if it could be repaired with a new handmade part

or if it was impossible to fix. What if a broken part could be taken out and replaced with a new, identical part? The gun would be usable again. This was the purpose of interchangeable gun parts.

Simeon North (1765–1852) owned a farm and a mill in Connecticut. North's mill manufactured metal scythes. North also took orders to make pistols. Both products were known for quality and durability.

The U.S. government contracted with North in 1799 to manufacture 500 pistols, when guns were produced one at a time. Craftsmen made all the parts for each gun and then assembled it. North and others worked to develop guns with interchangeable parts. He chose a different assembly method to fulfill a government contract in 1808: he had one worker make numerous copies of only one part of a gun while another worker made copies of another part, and so on, until all the gun's parts had been produced in quantity. Then a gunsmith took one of each part and assembled a gun. Using this method, more guns were produced in less time.

Handmade parts were not completely interchangeable, so any irregularly shaped parts had to be milled or shaved to exact sizes to fit together properly. If gun parts didn't fit precisely, the gun wouldn't work. North's 1813 government contract stated that the guns he manufactured would consist of parts that could be exchanged with any other gun produced at the same time. Only a machine could produce multiple copies of a part of uniform size and shape. Many credit North as the inventor of the first milling machine—which cuts metal in a pattern or shape to exact specifications.

North's milling machine produced parts that were the closest to achieving interchangeability at the time; yet they were not 100 percent interchangeable. Parts' dimensions were checked with gauges for accuracy, and workers still had to file some of them to complete a gun assembly. Machine tools were needed for precision cuts to achieve interchangeable parts, and jigs were developed to guide the exact dimensions of the machine cut. Devices were developed to hold a sheet of metal being cut without movement so that a precision cut could be achieved.

U.S. armories as well as private arms makers worked to produce interchangeable parts. The military saw the value of these parts because with them, guns broken on the battlefield could be repaired on the spot. The U.S.

armories in question were in Springfield, Massachusetts (established 1794), and Harper's Ferry, Virginia (founded 1798). Armories maintain and store firearms and ammunition, and some also manufacture firearms.

Thomas Blanchard (1788–1864) was an outside contractor for the Springfield Armory to make wooden rifle stocks. Blanchard became an inside contractor in 1822, which gave him the use of the armory's shop, tools, water power, and raw materials. Within four years, rifle stocks were being produced by a series of machines that Blanchard invented.

John H. Hall (1781–1841) patented the breech-loading rifle in 1811. Hall oversaw its manufacture at the Harper's Ferry Armory Rifle Works. The M1819 rifle's advantages over a muzzle-load rifle were its speed of load and reload, reliability, endurance, and its interchangeable parts. Hall invented several special-use machines to cut the wood and metal pieces of a gun to precise specifications as well as a system of gauges (work, inspection, and master) to measure accurately the size and shape of the machine-made parts.

Private arms makers and government armories achieved interchangeable gun parts by use of machine and gunsmith precision filing by 1828. It would be over 70 years before 20th-century technological advances improved machine precision to be greater than a skilled 19th-century gunsmith's precision with a file and gauges.

Linda Briley-Webb

See also Machine/Gatling Gun

Further Reading

Hounshell, David A. 1984. *From the American System to Mass Production, 1800–1932*. Baltimore: The Johns Hopkins University Press.

Muir, Diana. 2000. *Reflections in Bullough's Pond*. Hanover, NH: University Press of New England.

Inverted Microscope

The inverted microscope has its light source above the scope stage, while the objects to be viewed are placed below the stage, pointing up. The inverted microscope was invented by John Lawrence Smith in 1850.

Smith (1818–1883) was a professor of chemistry at the University of Louisiana (now Tulane University) when he invented the inverted microscope. His broad research interests included agricultural chemistry, geology, and mineralogy. He first described his invention to the Société de Biologie in Paris in 1850 and then to the American Scientific Association in 1851. The microscope was originally manufactured by Nachet in Paris, but since the company did not mention the inventor's name, Smith gave a full description of his invention in the *American Journal of Science and Arts* in September 1852.

The inverted microscope was designed to overcome the shortcomings of other microscopes used at that time in chemical and geological research. According to Smith, traditional microscopes constrained the user's ability to manipulate objects because of the limited space between the object and the stage. Moreover, condensation and vapor from objects would obscure the view. Finally, it was impossible to heat the objects under view without damaging the microscope. He solved these problems by placing the object beneath the stage and the microscope optics above it.

The inverted microscope allows users to handle large samples as well as those that must be kept under particular conditions (for example, in a thermostatic chamber). Unlike other microscopes, the inverted microscope situates the objective below the specimen, and light comes from above via a condenser before being diverted via a prism. In Smith's design, the prism has angles of 55°, 52.5°, 107.5°, and 145°. The light from the source goes through the specimen and then, via prism, is directed to the output eyeglass, which is mounted on a tube inclined at an angle of 35°. Focus is achieved by a clever system of three tubes that slide onto each other—one is fastened to a plate attached to the prism, while the middle one keeps the projecting collar and rests on two springs. The up-and-down movement of the focus assembly is achieved by moving a screw. This design allows the prism to remain accessible and to be wiped off before observation.

In addition to the ability to accommodate large samples and those that need a special environment, the inverted microscope allows the use of different illumination for observing structures in reflected light.

Modern inverted microscopes are commonly used to study chemical reactions and in metallurgy, and those used in microphotography and cinemicrography are designed to hold cameras.

Stefka Tzanova

See also *Vol. 3, Sec. 1*: Magnetic Resonance Imaging (MRI)

Further Reading

Smith, J. L. 1852. "The Inverted Microscope—A New Form of Microscope." *American Journal of Science and Arts* 14: 233–41.

Wilson, Catherine. 1997. *The Invisible World: Early Modern Philosophy and the Invention of the Microscope*. Princeton, NJ: Princeton University Press.

Jervis, John B. (1795–1885)

John Bloomfield Jervis was an American civil engineer known for his design and supervision of the construction of five of America's earliest railroads. He was also the chief engineer of three canal projects and built the 41-mile Croton Aqueduct, which was New York City's fresh water supply line from 1842 to 1891. He designed the first American locomotive truck, the Sturbridge Lion.

John Jervis was born in Huntington, New York, on December 14, 1795, and would be the oldest of the seven children of Timothy Jervis. With his family, he moved to Rome, New York, where his father ran a lumber business. John was an axe man who cut down bushes and trees along the Erie Canal, eventually working as a resident engineer in charge of a section 17 miles long. He was promoted to general superintendent of the Eastern Division of the Erie Canal in 1824. He left that job and became a chief engineer of Delaware and Hudson Canal Company, where he designed the Sturbridge Lion. He retired in 1864 and died in Rome, New York, on January 12, 1885.

Johnson D. Ton

See also Railroads; *Vol. 1, Sec. 2*: Erie Canal; Steam Engine

Further Reading

Coyle, John J., Robert A. Novack, Brian A. Gibson, and Edward J. Bard. 2010. *Transportation: A Supply Chain Perspective*. Boston: Cengage Learning.

LeMeassena, Robert A. 1991. *Articulated Steam Locomotives of North America*. Vol. 2. Marlborough, MA: Sundance.

Land Mines

A land mine is an explosive device that is usually concealed underground and whose purpose is to destroy or disable enemy soldiers. The mines usually detonate with the application of pressure, although other means have been used, including using trip wires or lit fuses to ignite the device. The land mine can cause damage in two significant ways: either by the blast itself or by the shrapnel thrown by the explosion. Mines are generally defensive weapons, especially when the attackers' path is known or they can be funneled into a specific area.

The American Civil War is considered the first modern war in part because of its devastating and controversial new weapons, including the land mine. The land mine was perfected by Gabriel Rains (1803–1881), a Confederate officer. Union and Confederate members alike criticized this device, considering it barbarous and ungentlemanly. Despite its detractors from within the Confederacy, it became a staple in all future wars, bringing military conflicts into the modern age.

The first documented use of a pressure-detonated mine is in the *Huolongjing*, a 14th-century military treatise that recorded weapon use. A military engineer of German descent, Samuel Zimmerman, significantly improved the land mine in Europe in the 16th century in the form of the *fougasse*—an improvised mine made by hollowing out the ground and filling it with black powder and projectiles that could be detonated by pressure.

Gabriel Rains created the first mechanically fused, high-explosive antipersonnel land mines in the United States. Rains, a West Point graduate, served in Florida and Louisiana during the Second Seminole War and also recruited troops for the war with Mexico. During

his time in the United States Army, he became well known for experimenting with explosives. When North Carolina seceded from the Union in 1861, he resigned his commission as a lieutenant colonel and joined the Confederacy as a colonel, quickly moving up to the rank of brigadier general by September of the same year.

The first use of the land mine during the American Civil War came while Rains was leading troops in a retreat from the battle of Yorktown. While fighting a rear-guard action, Rains's troops buried 8" and 10" artillery shells with fuse primers. As the Union troops activated these makeshift land mines by stepping on them, panic spread and entire companies retreated. Rains quickly found more of these makeshift land mines and buried them to protect the Richmond area. Though Rains was an unsuccessful brigade commander and drew heavy criticism from Confederate commander Daniel H. Hill at the Battle of Seven Pines in 1862 for his failure to attack Union troops, he made a name for himself by developing land mine technology. As his reputation for working with explosives spread, the Confederate War and Navy Departments called upon him to discuss the use of exploding mines.

Rains started off fairly simply by filling tin cans with powder that had trigger attachments to set them off, but these offered little in the way of destructive power. Soon after, he developed a mine that could be used on both land and water that became known as the "Rains Patent." The Rains Patent mine was made of sheet iron and was filled with powder and shrapnel; it had a fuse connected to a brass percussion cap. When pressure was placed upon the mine, the cap would ignite the fuse and set it off. These mines became a useful weapon to the Confederacy, especially because it was fighting a defensive war and, more important, because the objective of the Union in the Eastern Theater was to capture Richmond. Rains believed that more than 1,300 land mines surrounded the capital by 1864.

Soon after seeing the effectiveness of the land mine, the Confederates began to use them around houses, shops, telegraph poles, and even hidden in sacks of flour. They were especially effective in guarding fortifications. Confederate soldiers defending Charleston in South Carolina, Battery Wagner, Morris

Island, Fort Sumter, Fort McAllister, and Fort Fisher used the Rains Patent land mines. The troops under William Tecumseh Sherman were plagued by land mines throughout their march to the sea in 1864. The mines became such a problem for Union forces that Sherman started marching Confederate prisoners in front of the Union columns as human minesweepers. There are no official records that Union soldiers made use of the land mine during the Civil War, because Union forces strongly opposed mine warfare and deemed it murderous and barbarous. Also, the Union army very seldom found itself in a defensive position.

Gabriel Rains, after creating the "Rains Patent," established mines for use in the water that protected the harbors of the South and deterred Union ships from traveling the waterways. Although all of his efforts were in vain for helping the Confederacy win the war, he laid the groundwork in creating an effective and deadly land mine that would be used as a template for those of future generations.

Scott Russell

See also Military Technology (Civil War)

Further Reading

Croll, Mike. 1998. *The History of Landmines*. Barnsley: Pen & Sword Books.

Schneck, William C. 2006. "The Origins of Military Mines." *Major Engineer Bulletin* (July).

Youngblood, Norman E. 2006. *The Development of Mine Warfare: A Most Murderous and Barbarous Conduct*. New York: Praeger.

Long, Crawford Williamson (1815–1878)

Crawford Williamson Long was an American surgeon and pharmacist who pioneered the use of sulfuric ether as an anesthetic for surgery. His application for an anesthetic is a successor to Humphry Davy's use of nitrous oxide in 1800. Today, nearly all surgeons use some amount or form of anesthesia to aid them in their work.

Long was born in Danielsville, Georgia, and died in Athens, Georgia. Long studied under Benjamin Dudley, a famed surgeon, witnessing patients undergoing

surgeries without the use of sedatives or anesthetic. During his studies, Long saw the effects of hypnotism and nitrous oxide on people. Noticing that people who used nitrous oxide recreationally did not feel pain when injuring themselves, he began to use anesthetics, choosing sulfuric ether.

Anesthesia is used to enable medical procedures to be performed on patients with reduced or no pain. The three categories of anesthesia are: general anesthesia, sedation, and regional anesthesia. The first forms of general anesthesia were herbal remedies used by early humans. Alcohol has been a common and prevalent sedative used since ancient times. Experimenting on himself, Humphry Davy found nitrous oxide, which was previously thought to be lethal, to be an anesthetic.

In March 1842, he successfully removed a tumor from the neck of a young man while employing his anesthetic. Despite his success, Long did not publish his findings, as he wanted to be very sure of his work. In the December 1846 issue of *Medical Examiner*, a Boston dentist named William Morton was cited as claiming that he had used ether as an anesthetic. The subsequent, January 1847 issue presented various experiments in using ether. Long wrote up his own findings and account of his discovery and presented them to the Medical College of Georgia in 1849. While there was a controversy over who had discovered the use of ether, Long merely sought the recognition of his peers and the well-being of his patients.

In 1842, Long married Caroline Swain, with whom he had 12 children. In 1851, he and his family moved to Athens, Georgia, where he and his brother, Robert, began practicing pharmacy. During the Civil War, he served as a surgeon and treated soldiers on both sides of the conflict. On June 18, 1879, Long was declared as the discoverer of anesthesia by the National Eclectic Medical Association.

Dan Tran

See also Anesthesia; Civil War Medicine; Maynard, Edward

Further Reading

Fradin, Dennis Brindell. 1996. *We Have Conquered Pain: The Discovery of Anesthesia*. New York: Margaret K. McElderry.

Jacobs, Joseph. 2012. *Some Personal Recollections and Private Correspondence of Dr. Crawford Williamson Long: Discoverer of Anaesthesia with Sulphuric Ether: Together with . . . of His Priority in This Wonderful Discovery*. Reprint ed. Ann Arbor: University of Michigan Press.

Machine/Gatling Gun

The first guns were manually loaded one round at a time, and pulling the trigger fired that round. Revolvers changed this. Revolvers loaded multiple rounds, but one pull of the trigger still only fired one round. Machines that made gun parts repeated the same task over and over. Inventors wanted to devise a gun that fired over and over: a gun that worked like a machine.

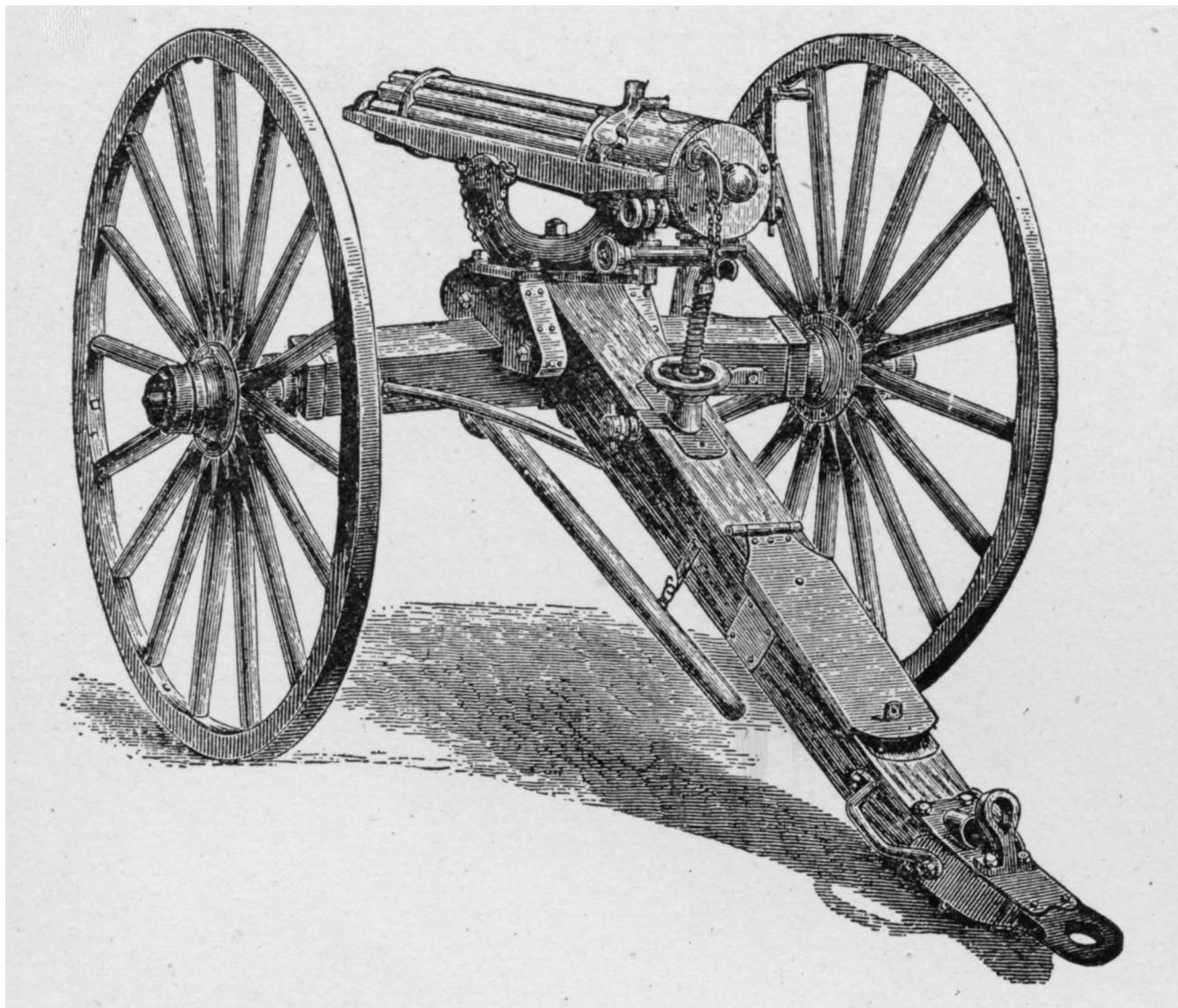
James Puckle (1667–1724) invented a single-barrel firearm that held nine rounds. Each round rotated in place and fired by means of a hand crank. It could fire 63 rounds in seven minutes. The multishot weapon that Wilson Agar invented in the 1800s could fire about 120 rounds per minute.

Dr. Richard Gatling (1818–1903) invented a weapon that could fire hundreds of rounds per minute. The multiple-shot, multiple-barrel Gatling gun was patented in 1862 (U.S. Patent 36,836).

The first Gatling guns had funnel-shaped hoppers or containers to hold loose rounds of ammunition. The gunner turned a hand crank to rotate the gun's barrels. When one of its six barrels moved past the hopper, it picked up a cartridge. Continuing to crank caused the round to fire, rotated the barrels, and expelled the empty round and picked up a loaded one. The gun fired as fast as the crank was turned and continued to fire until the crank stopped turning or it ran out of ammunition.

The Gatling gun was heavy and difficult to move. It was mounted on a two-wheel carriage and required several people to move it. Previous multiple-shot weapons overheated from repeated firing. The Gatling gun's multiple barrels dispersed the heat created when firing, so it was less likely to overheat.

Hiram Maxim (1840–1916) invented the first self-powered or automatic machine gun and patented it in 1884. The Maxim gun had a single barrel. Rounds were held in individual pockets of a cloth ammunition



A precursor to the modern machine gun, the gatling gun, also known as a rotary cannon, was used by the Union Army during the American Civil War. (Ridpath, John Clark, *Ridpath's History of the World*, 1901)

belt that fed into the gun. The first round was cocked by hand. The trigger pulled and was not released. The energy from the propellant charge explosion pushed in all directions, and the energy pushed the round down the barrel. Energy that pushes in the opposite direction is called “recoil.” The Maxim gun harnessed the recoil energy to push the empty round out of the gun and also a loaded round into place, ready to be fired. The Maxim continued to fire until the trigger was released or the gun was out of ammunition.

The Maxim gun had a unique cooling system that resembled a water jacket around the barrel. As the water

cooled the barrel, the water’s temperature increased, creating water vapor. Later models captured the vapor in a reclamation system that recycled it. Vapor was fed into a reservoir. When the vapor cooled, it returned to the liquid state and was fed back into the jacket. Maxim guns fired 500 to 600 rounds per minute.

A variation of the automatic machine gun was invented by John M. Browning (1855–1926) and patented in 1890. Browning noted the explosion of energy out to the muzzle when a round fired. Browning developed a method to capture that force. This led to the Colt Model 1895 automatic machine gun.

This gun's barrel had a small hole in the bottom muzzle end that captured some of the gas produced when the charge exploded and pushed the bullet down the barrel. The gas pushed a lever that opened the breech, and a spring forced a loaded round into place, ready to fire. Browning's machine gun was fed by an ammunition belt and could fire 400 rounds per minute.

Browning designed the gun with a thicker single barrel, so no cooling system was needed. It weighed less, so it could be mounted on a tripod. Shooters were taught to fire in short bursts instead of with prolonged, repeated fire to decrease the likelihood of overheating.

Manual machine guns weren't used much after automatics were invented. Browning's machine gun was used during World War I (1914–1918). Maxim's machine gun was modified and still in use in the 1950s. Modern automatic machine guns are variations of these models.

Linda Briley-Webb

See also Colt Revolver; Interchangeable Gun Parts; Repeating Rifle

Further Reading

Pauly, Roger. 2004. *Firearms: The Life Story of a Technology*. Westport, CT: Greenwood Press.

Wahl, Paul, and Don Toppel. 1978. *The Gatling Gun*. New York: ARCO.

Mason Jar

John Landis Mason invented the mason jar in 1858. Mason jars (and jars like them) are the central piece of hardware in home canning.

While the early 19th century saw a plethora of self-sealing canning jars, most of them suffered from flaws. Tin lids lost their seal, and wax sealing was vulnerable to mold spoilage. John Mason patented a glass jar with a screw-finished neck onto which could be laid a flat lid and a screw-pressed metal ring. The mason jar rapidly became popular, particularly after Mason introduced a variety of jar shapes and glass colors. However, a glitch in Mason's patent allowed

other glass manufacturers to copy and alter Mason's design—so much so that by the 1870s, the market was flooded with canning jar types.

Charles de Quilfeldt of New York introduced the wire bale closing system, which became the most popular canning jar option of the late 19th and early 20th centuries. Wire bales affixed to the neck of jars allowed the lids to be clamped down with pressure. The seal was particularly good when used with a rubber O-ring between the lid and the neck of the jar. This type of jar is still readily available today.

Mason jars and their ilk are experiencing a renaissance in the early 21st century, given the resurgence in home canning and jar lunches.

Peg A. Lamphier

See also Vol. 2, Sec. 2: Blender; Hoosier Cabinet; Vol. 3, Sec. 1: TV Dinner

Further Reading

Harlan, Jessica. 2017. *Mason Jar Lunches: 50 Pretty, Portable and Packed Lunches*. Berkeley, CA: Ulysses Press.

Maynard, Edward (1813–1891)

Edward Maynard was an American dentist and firearms inventor. In 1831, he enrolled into the U.S. Military Academy at West Point but resigned due to health issues, and he became a dentist in 1835. While practicing dentistry, his clientele included congressmen and presidents, and it is reported that he declined the position of imperial dentist to Tsar Nicholas I. In 1857, Maynard became professor of theory and practice at the Baltimore College of Dental Surgery. Maynard had seven children with his first wife, Ellen, and none with his second wife, Nellie.

He was awarded 23 patents relating to firearms, the first of which was awarded in 1845 for a priming system that cycled a small mercury fulminate charge to the nipple of a percussion cap firearm. In 1845, the Maynard system was installed and successfully trialed on 300 converted percussion muskets. In 1851, he patented a simple lever-operated, breechloading rifle that

was loaded at the rear rather than from the muzzle, as his previous patent was deemed unreliable in combat.

While breechloading firearms had been invented in the 14th century, they only became more successful in the 19th century with improved precision in engineering, machining, and manufacturing. The difficulty with making reliable breechloading firearms was creating an adequate seal for the breech. This was overcome with the employment of self-contained metallic cartridges and the development of the interrupted screw.

The Maynard carbine was manufactured between 1858 and 1859 and was used in the American Civil War. Pressing on the gun's lever revealed the breech for loading, and raising the lever closed the gun's breech. It also employed the Maynard priming system. Over 21,000 of the carbine's various models were built.

In 1857, Maynard founded the Maynard Arms Company with the help of financial backers. He contracted the Massachusetts Arms Company to manufacture Maynard carbines for both civilian and military use. While the Maynard was acclaimed in frontier service, only four U.S. regiments were armed with the first model during the American Civil War. In January 1861, the Massachusetts Arms Company's factory burned down, possibly contributing to the relatively low rate of distribution. In 1888, he held the chair of dental theory and practice at National University in Washington, D.C. Maynard died on May 4, 1891. He is buried at the historic Congressional Cemetery in the District of Columbia.

Dan Tran

See also Maynard Carbine; Military Technology (Civil War); *Vol. 1, Sec. 2: Interchangeable Parts*

Further Reading

- Hatch, Rodney S., III. 2010. *Dr. Edward Maynard: "Letters From the Land of the Tsar, 1845–1846"—America's Pioneering Dental Surgeon Turned Civil War Gun Inventor*. Waynesboro, PA: Ironhorse.
- Johnson, Melvin Maynard. 1941. *Automatic Arms: Their History, Development, and Use*. New York: Skyhorse.

Maynard Carbine

The Maynard carbine was a popular firearm that utilized a breechloading design that replaced the flintlock. It was considered one of the best-performing and most accurate carbines of the American Civil War era. Two models of the Maynard carbine were produced. The first was simply known as the "First Model," with approximately 5,000 produced between 1858 and 1859. The "Model 1863" saw production of about 20,000 between 1863 and 1865 amid the American Civil War (1861–1865).

Inventor and dentist Dr. Edward Maynard (1813–1891) was credited for many patents in the field of dentistry and firearms in his time. Shortly after his resignation from the U.S. Military Academy at West Point in 1831, Maynard began pursuing the profession of dentistry in 1835. As a natural mechanic and skillful welder, Maynard took great pride in his ability to make his own dental instruments at a time when standardized equipment was not yet established. His dental practice would land him in Washington, D.C., where his clientele grew to include distinguished members of the country's political elite. Tsar Nicholas I asked him to become the imperial dentist after the emperor's surgeon witnessed an operation performed by Maynard. He declined the offer and continued his practice in Washington, D.C., for the rest of his life. Maynard would go on to accept the chair position for Theory and Practice of Dentistry at the Baltimore College of Dental Surgery from 1856 to 1860, and he later accepted the same position in the faculty of the Dental Department of the National University at Washington from 1887 to 1889. He was also the recipient of several honorary degrees such as an AM from Columbia College in Washington, D.C., an MD from Western Medical College in 1840, and a DDS from the Baltimore College of Dental Surgery in 1841. Maynard died on May 4, 1891, at the age of 78 from Bright's disease, which involves inflammation in the kidneys. He had retired from his practice as a dentist a year prior due to failing health. He had been married to Ellen Sophia Doty of Sherburne, New York, in 1837 and had six children. She would later die on October 3, 1863, in Cooperstown, New York. Six years later, he

wedded Nellie Long of Savannah, Georgia, in 1869, and they had one daughter together.

Despite his contributions in the field of dentistry, Maynard is best known for his contributions in firearms. One in particular was his breechloading rifle design in the Maynard carbine that he patented on May 27, 1851. It is a single-lever operated design that primarily fired a 0.52-caliber metallic cartridge. The lever operated the breech for loading the weapon. Depressing and raising the lever opens and closes the breech. A major issue to overcome at the time in the early development of breechloading rifles was escaping gas at the breech, but Maynard's use of a metallic cartridge and a slight gap between the breech and the receiver helped seal the gas in.

There were two versions of the Maynard carbine: the "First Model" and the "Model 1863." Production of the First Model was made possible after successful army test trials on May 16, 1856, sparked the interest of several to form the Maynard Arms Company of Washington, D.C., in April 1857. Through the Massachusetts Arms Company, 5,000 First Models were manufactured and appeared on the market from 1858 to 1859. They had a patch box in the stock and Maynard's tape primer system. Another 400 were purchased from the secretary of war for U.S. Army use after a second army test trial. The Revenue Cutter Service (a.k.a. the U.S. Coast Guard) and the U.S. Navy followed suit with 100 and 50 respectively. Although 400 were purchased, between 1861 and 1863, only the 1st (later 4th) U.S., 9th Pennsylvania, and 1st Wisconsin Cavalry were ever issued the First Model.

On January 28, 1861, the Massachusetts Arms Company's factory was destroyed by fire. It was later rebuilt in 1863 and produced the second version of the Maynard carbine. Between 1863 and 1865, 20,000 units were built. This model was equipped to take the more traditional percussion caps that proved to be more reliable than Maynard's system, and it lacked the patch box in the stock and also the tang sight that was used on the First Model. Delivery of the Model 1863 to arm the federal cavalry began in June 1864 and continued until May 1865. Despite being issued late in the war, the 9th and 11th Indiana regiments, along with the 11th Tennessee Cavalry, were partially equipped

with the Model 1863. The rest saw little or no service and were left in arsenals until they were sold off by the government in the late 1860s. Use of the Maynard carbine was not limited to Union forces.

Prior to Abraham Lincoln's election to president in November 1860, the First Model was purchased by Southerners for sporting purposes. Approximately 1,500 of 5,000 First Models were purchased from the Maynard Arms Company a month before Lincoln took office. The remaining inventory was sold off six months following the 1860 election. Over 90 percent armed the Southern militia companies that were forming throughout the states of Mississippi, Florida, and Georgia. The Maynard Arms Company also entered into contracts with two Mississippi senators for 800 First Model carbines on December 20, 1860, and 1,000 more with the state of Georgia on December 18, 1860. Louisiana and South Carolina also purchased the firearm prior to the start of the Civil War. The number of First Models in soldiers' hands only grew with Confederate forces seizing control over federal arsenals located in the Southern states. Indeed, the First Model was listed as an official firearm in Confederate ordinance manuals.

Cartridges for the carbine were simple to make, which proved to aid Confederate forces, as the South lacked complex manufacturing facilities. The popularity of the rifle came with its ease of use, maintenance, and simple construction. Praised for its accuracy by Confederate sharpshooters, the folding rear sight allowed the user to fire at 100, 200, and 300 yards once aligned with the forward post sight. Trained marksmen had been known to hit their targets at 600 yards at nearly 12 rounds per minute. It was relatively compact at 40 inches long with a 20-inch barrel.

Production continued through the Massachusetts Arms Company beyond the conclusion of the Civil War in 1865. By then, special accessories allowed the carbine to be converted to chamber a thick based Maynard centerfire cartridge. Gaining high regard as a centerfire target and hunting rifle, Dr. Maynard's design outlived many other Civil War carbines. The 1890s saw several changes that ended the production of the Maynard carbine. The rising popularity of the repeating rifle and the changing climate in manufacturing practices may have

caused the bankruptcy of the Massachusetts Arms Company, resulting the demise of the Maynard Carbine.

Chi Lao

See also Dahlgren Gun; Interchangeable Gun Parts; Machine/Gatling Gun; Maynard, Edward; Repeating Rifle; *Vol. 1, Sec. 1: Kentucky Long Rifle; Vol. 3, Sec. 1: M16 Rifle*

Further Reading

Edwards, William B. 1997. *Civil War Guns: The Complete Story of Federal and Confederate Small Arms: Design, Manufacture, Identification, Procurement, Issue, Employment, Effectiveness, and Postwar Disposal*. Gettysburg, PA: Thomas.

McAulay, John D. 1991. *Civil War Carbines*. Vol. 2. Lincoln, RI: A. Mowbray.

Thorpe, Burton Lee. 1904. "Edward Maynard, A.M., M.D., D.D.S., a Born Mechanic, an Exquisite Operator, and the Inventor of the Maynard Rifle." In *Dental Brief: An American Journal of Dental Science, Art and Literature*, vol. 17, edited by Thomas Bromwell Welch, Wilbur L. Litch, and Alfred P. Lee, 363–69.

McCormick, Cyrus (1809–1884)

Cyrus McCormick was an inventor and businessman whose creations and innovations changed the face of 19th-century American farming. The mechanically adept McCormick left his life as a farmer and turned to inventing. The products of his work, coupled with his business acumen, were critical to the development of the nation's agricultural heartland, and the sum of his efforts ultimately served to revolutionize the American agricultural landscape. In particular, his invention and development of the mechanical reaper changed the nature of agriculture in the heartland, allowing farmers on the new frontier to move beyond single-family farms and to profit from increasingly large farms.

Cyrus McCormick was born on February 15, 1809, in Rockbridge County in the Shenandoah Valley of Virginia. The oldest of eight children born to Robert McCormick and his wife, the former Mary Ann Hall,

McCormick received little formal education. However, from an early age, he liked to tinker in his father's workshop on the family farm. Indeed, at only 15 years old, he came up with the idea for a cradle to transport grain. That invention would prove to be only his first that would ultimately change the face of farming. His greatest invention, the reaper, represented not only his impressive mechanical and engineering skills but also his perseverance, for he developed it in part out of early experiences and some preliminary designs over which his father had toiled for a number of years. By adding his own mechanical input and ideas, in 1831, McCormick first demonstrated not only a viable piece of farm machinery but a revolutionary one. While the initial model, demonstrated for the first time in 1831, did not adapt well to varying conditions, McCormick quickly fixed that problem, and in 1834, he secured a patent.

The young inventor then undertook the challenge of convincing a skeptical population of farmers of the value of his reaper. The need to make it viable commercially was heightened when, in the aftermath of the Panic of 1837, the McCormick family foundry failed. This led Cyrus to put an even greater focus on the reaper. Slowly, as knowledge of the new invention spread, it became marketable, and sales grew from 2 in 1841 to 7 in 1842 to 29 in 1843 and a burgeoning 50 in 1844. The following year, McCormick secured a new patent on an improved reaper, and in 1847, forming a partnership with Chicago Mayor William Ogden, who provided the major funding, established a factory in the city and, by the following year, sold 800 reapers. Sales continued to grow, and McCormick was soon able to buy out Ogden. However, as distribution widened, so did those who copied the design. As the time came to renew his original patent, McCormick found himself mired in ongoing and hard-to-win patent battles.

Recognizing the difficulty of obtaining the exclusive rights to his product, he instead turned to some unusual and innovative business practices to secure his fortune and establish his place at the forefront of the farm machinery business. Taking advantage of the growing railroad network crisscrossing the nation, McCormick advertised extensively and dispatched high-publicity salesmen who, traveling widely, got into local communities where they educated farmers

about the benefits of the new technology and offered public demonstrations of it. In addition, McCormick offered product warranties and written guarantees while also developing a system of mass production that helped make replaceable parts easily available. Also, in an effort to get his machine into the fields, since that would serve as its best form of marketing, McCormick offered lenient credit for purchasers.

Soon, the McCormick Reaper was known and used across the country, and that success was followed soon afterward by its introduction in Europe. Indeed, in 1851, McCormick introduced his machine at the Great Exhibition in London, where it was awarded the grand prize. Four years later, McCormick emerged triumphant from the French International Exposition, with the reaper earning the Grand Medal of Honour. By 1856, the McCormick Harvesting Machine Company—which, under the leadership of his son Cyrus McCormick Jr., would eventually become International Harvester—sold 4000 machines.

When the company's factory was a victim of the 1871 Chicago fire, McCormick's wife urged him to rebuild, and in 1873 a new, larger factory was opened. As the company thrived, McCormick, a notorious workaholic, began to turn some of his considerable energies to civic and philanthropic endeavors. He was an active and longtime supporter of the Presbyterian Church and was also the principal supporter and member of the board of trustees of the McCormick Theological Seminary in Chicago. In addition, McCormick was an active supporter of the Democratic Party. Retaining ties to his native Virginia, McCormick was

a generous financial supporter of Washington and Lee University while also serving as a trustee for the last 20 years of his life. A statue of McCormick was later erected on the university's front campus.

While he had struggled in the beginning to convince people of the value of his work, by the end of his life, he was being honored in numerous venues, including election as a corresponding member of the French Academy of Sciences in recognition of his having done so much for the cause of agriculture.

McCormick had married his one-time secretary, the former Nancy "Nettie" Fowler, in 1858. The couple had seven children. In 1880, he turned control of the company over to his son Cyrus Jr. The active and vigorous McCormick suffered a stroke in 1880 that left his legs paralyzed for the last four years of his life. Cyrus McCormick died on May 13, 1884, at his Chicago home. He is buried in Graceland Cemetery.

William H. Pruden III

See also Combine Harvester; Mechanical Reaper; *Vol. 1, Sec. 2: Interchangeable Parts; Steam Tractor; Three-Piece Iron Plow*

Further Reading

Casson, Herbert Newton. 2005. *Cyrus Hall McCormick: His Life and Work*. New York: Cosimo Classics.
 Creighton, Jeff. 1996. *Combines and Harvesters: Photographic History*. Richardson, TX: Motorbooks.
 Macmillan, Don. 2014. *The Bigger Book of John Deere: The Complete, Model-by-Model Encyclopedia*. McGregor, MN: Voyageur Press.

Primary Document: Letter of Robert E. Lee to Cyrus McCormick Regarding the Curriculum at Washington College (1865)

Immediately after his surrender in April 1865, Robert E. Lee took the job of president of Washington College. Cyrus McCormick made a gift of money to the college, which then instituted a shift in curriculum from pure classical education to one that included science and technology classes. The following is the letter that Lee wrote to McCormick about the educational shift at the college.

Washington College
 Lexington VA: 28 Nov 65

Sir

At a late meeting of the Board of Trustees of Washington College, it was resolved, with a view to a more thorough & extended course of scientific instruction; & to the liberal & practical education of the industrial

classes; to establish five additional Professorships; without interfering with the regular classical & literary course.

The Professorships proposed are those of Practical Chemistry, Experimental Philosophy & practical mechanics, Applied Mathematics, Modern Languages, History & Literature.

Such a course of instruction, is requisite to meet present events of the country; & enable those young men who do not desire to devote themselves to special professions, requiring specific studies after graduating, to enter at once upon the active pursuits of life. To you who are so conversant with the necessities of the country, & its vast underdeveloped resources; the benefit of applying scientific knowledge & research, to agriculture, mining, manufacturing, architecture, & the construction of ordinary roads, R. Roads, canals, bridges etc., will be at once apparent; & it is hoped will elicit your approval. To provide the funds necessary for the execution of this project, the Board of Trustees rely upon the patriotism of the people; & the citizens of Rockbridge &

adjacent counties, notwithstanding their impoverished condition; are responding with generosity, which they always evince towards measures of national importance. Their efforts I am sure, will be strengthened by your sympathy; & your influence will cheer them in their meritorious work. The success of their cherished design, I am equally sure, will be peculiarly gratifying to me, who has already done so much for the advancement of agriculture & the relief of the husband-man; not only of his native state, but for a grateful world; & it is this consideration that has emboldened me, to bring it to your notice.

I am Sir with great respect

Your obt servt
R E Lee

Source: Transcribed from the Wisconsin Historical Society, Robert E. Lee, Letter from Robert E. Lee to Cyrus McCormick, Image 82931. Available at: <https://www.wisconsinhistory.org/Records/Image/IM82931>.

Mechanical Reaper

Invented in 1831, Cyrus McCormick's mechanical reaper changed the face of American agriculture. A product of years of work that actually had been started by McCormick's father on their farm in Virginia, the reaper had an incalculable impact on both farming and the national economy.

Prior to the invention of the reaper, American farmers had harvested grain through a manual process dating back to the beginning of agriculture. Farmers would cut the standing grain by wielding a hand-swung scythe and were followed by another set of workers, the binders, whose job was to tie the cut grain into bales that were carted away and stored, generally in barns. This onerous process required more labor than did the actual planting. Consequently, the amount of acreage that could be planted was limited by the harvesting process.

It was this problem that McCormick's reaper addressed. The machine's roots could be traced to the longtime interest of Robert McCormick, Cyrus's father, in developing a method for harvesting more

and doing it faster. After years of work trying to develop the appropriate tool, he abandoned the project in 1831, only to have the mechanically adept Cyrus step in and adapt and develop his father's basic work in a way that made agricultural history. Indeed, once he had the idea sketched out, it took less than two months to build and field-test a prototype.

In its original form, the reaper could increase a farmer's yield by 10 times with comparatively little effort by the attendant farmer, and while the initial model first demonstrated in 1831 did not adapt well to varying conditions, McCormick quickly fixed the problem. Despite the way the reaper streamlined the labor-intensive process of cutting, threshing, and bundling grain, all while being pulled by a horse, it would be almost a decade before farmers began to buy it. But in that intervening time, McCormick continued to work on his creation, fine-tuning its operation—the early version was particularly noisy and required a person to walk alongside to calm the horses.

In 1834, McCormick received a patent for his mechanical reaper. In an effort to create a market for

the machine, McCormick undertook some innovative business practices. Taking advantage of the nation's growing railroad usage, he sent salesmen out into the community, arranged demonstrations, and offered written guarantees and lenient credit for purchasers while also making replaceable parts easily available.

In the early 1840s, the idea of a mechanized reaper took hold, and in 1845, McCormick secured a new patent on an improved reaper. In 1847, he built a factory in Chicago, and the next year, sales reached 800. In the early 1850s, McCormick introduced the reaper in Europe, where it won awards at expositions in London and Paris. Despite continuing patent battles, sales on both sides of the Atlantic boomed.

Meanwhile, McCormick continued to refine his creation. In 1872, the company produced a model that automatically bound the bundles with wire, and in 1880, it began selling a binder that used a knotting device that bound bundles with twine.

While the reaper would eventually give way to the self-propelled combine, it nevertheless was a critically important first step in the direction of mechanized farming. It revolutionized farming while significantly impacting the American economy.

William H. Pruden III

See also Combine Harvester; *Vol. 1, Sec. 2: Interchangeable Parts; Steam Tractor; Three-Piece Iron Plow*

Further Reading

Casson, Herbert Newton. 2005. *Cyrus Hall McCormick: His Life and Work*. New York: Cosimo Classics.

Creighton, Jeff. 1996. *Combines and Harvesters: Photographic History*. Richardson, TX: Motorbooks.

Wong, Patricia. 1992. "McCormick's Revolutionary Reaper: Making Illinois the Hub of Agriculture." *Illinois History* (December). <http://www.lib.niu.edu/1992/ihy921205.html>, accessed August 22, 2018.

Merrick, Solymon (1806–1852)

Solymon Merrick patented the first wrench in 1842. Wrenches tighten bolts and screws much tighter than someone can do it by hand. Merrick's patent helped pave the way for multiple job industries to flourish, as it allowed for a unified system to be created for screws

that were used to tighten bolts, as well as equipment used in numerous industries. Before the wrench was called a wrench, it was known as a "spanner."

Solymon Merrick was born into a free black family in 1806 in Massachusetts. He probably developed the wrench in 1835, but he didn't patent his design until 1842. Other inventors followed suit, creating different types of wrenches such as the monkey wrench, ratchet, and pipe wrench. This cropping up of new and unique types of wrenches shows how revolutionary Merrick's invention was, since there was no readily available substitute.

The wrench that Solymon design had a slanted head, which meant that the user could set the wrench in place at an odd angle and rotate it to correct the angle. The bent neck functioned as a kind of built-in user's manual.

In his lifetime, Merrick filed 11 patents, all of them between 1834 and 1851. Seven of them are for wrenches, including a quick-adjust wrench and several nut wrenches, but he also patented two leather punches and a machine for making barrel staves. He died in 1852 in Springfield, Massachusetts.

Charles Moncky invented the monkey wrench in 1858, while Daniel Stillson invented the pipe wrench in 1870. Robert Owen Jr. patented the ratchet wrench in 1913. The wrench has arguably been one of the greatest but most unappreciated inventions of the 1800s and is an international symbol for the handyman.

Peg A. Lamphier

See also Ratchet Wrench; *Vol. 1, Sec. 2: Circular Saw; Interchangeable Parts; Internal Combustion Engine*

Further Reading

Rathbone, P.T. *The History of Old Time Farm Implement Companies and the Wrenches They Issued*. Self-published: P.T. Rathbone, 1999.

Military Technology (Civil War)

The technological advancements that were made during the American Civil War are why many historians consider it first modern war. The most significant advancements took place in weaponry, but there were

others in medicine, photography, the telegraph, submarines, locomotives, and many more fields.

Of all the technological advancements, changes in weaponry affected the average soldier the most. The tactics used during the Civil War were the same as in previous generations, but the weaponry became exponentially better, creating extremely high battlefield death tolls. The first weapons used were primarily smoothbore muskets, which had an approximate effective firing range of 80 yards. As the war progressed, the smooth bores were phased out and the rifled musket took its place. The rifled musket used the minié ball, a soft, conical lead bullet with rings that would expand to fit the rifling of the musket, therefore increasing its accuracy at 300 yards. “Rifling” refers to the helical grooves in the barrel of a gun that causes a bullet to spin, helping it to travel farther. The extended range of a rifled gun could be up to a half mile. The new rifled muskets also improved the rate of fire to approximately three rounds per minute by a trained soldier. With the large amount of new recruits filling the ranks of both the Union and the Confederate Armies, they were trained in tactics primarily with the smoothbore musket in mind. These relied on massed fire and condensed troops, making the switch from the smoothbore to the rifled musket much more devastating.

The Civil War was the first war to make use of detailed reports of medical history. Great care was taken to make notes on what worked and what did not, as well as to make records of injuries and the medical procedures that took care of them. This led to the publication of *Medical and Surgical History of the War of the Rebellion*, an early and important accomplishment in the field. In the first major battle at Bull Run, Virginia, the Union hospitals saw over 1,124 wounded, and the Confederate hospitals over 1,582. It was clear at this point that there had to be a system to handle mass casualties. Systems were quickly put in place that included field hospitals, aid stations, and permanent hospitals.

This was the first system ever set up to determine the severity of wounds and put operative procedures in place to take care of them. One of the major operations was amputation, and it was deemed best to do this within the first 24 hours of a wound for the best possible outcome. These systems and the early treatment of

soldiers were used as the template for treating soldiers during World War I, World War II, and the Korean War.

Another major finding of the Civil War was the correlation between disease and unsanitary conditions. English nurse Florence Nightingale’s work in the Crimean War in the decade before the American Civil War led her to conclude that sanitation and hygiene prevented infection, disease, and death among troops in the field and in hospitals. Civil War medical personnel were trained with these new ideas and standards in mind.

Surgical principles quickly advanced with the prevention and treatment of infectious disease with anti-septic agents, as well as the use of chloroform to reduce patients’ suffering. One of the biggest contributions to the future of the medical field was the U.S. Sanitary Commission. This was a private relief agency created by federal legislation on June 18, 1861, to support sick and wounded soldiers of the U.S. Army during the war. The Sanitary Commission was a civilian-organized and largely female-run soldier’s relief society that set the pattern for the development of the American Red Cross.

Although photographs of earlier conflicts do exist, the American Civil War was the first war to be extensively documented in photographs. Photographers traveled to the fields of battle and took pictures of the carnage there. The newest technology, wet-plate photography, involved a six-step process that included making a mixture called “collodion.” It contained ethyl ether and acetic or sulfuric acid. The photographer coated the glass plate in collodion, immersed the plate in silver nitrate in a dark room, and placed it in a light-tight container that was then put into the camera. The cap of the camera would be removed for two to three seconds, and once the image was captured, the plate was removed, taken to the darkroom, and developed. Special mixtures were used to make sure the image would not fade, and then the image could be printed to paper.

The telegraph, invented in 1844 by Samuel Morse, gave political leaders the ability to get near-instantaneous updates from the battlefields during the American Civil War. The usefulness of the telegraph was so apparent that during the war, over 15,000 miles of telegraph cable was laid for military purposes.

A telegraph works by sending a series of electric pulses through a long wire to another telegraph device, which then interprets the pulses into a series of clicking sounds. There is an “alphabet” called Morse code that the person on the other side of the telegraph can use to decipher the transmission according to how long the clicks are. Prior to the telegraph, messages had been carried by courier and took days or even weeks to get to their destinations. Military leaders were left to their own devices as to objectives as battles grew in intensity. Abraham Lincoln used the telegraph to bolster the confidence of his generals as well as to propel his leadership vision to them. Most important, he used it as a tool to gather information and understand what was going on in the headquarters of his military leadership. Not only did it allow him to be in contact with his military leaders, it also allowed the generals to communicate to one another over vast distances.

The Confederacy also made use of the telegraph, although not to the extent that the Union did. In the Eastern Theater, Robert E. Lee was constantly on the move, traveling hundreds of miles to Maryland and Pennsylvania, and he quickly moved out of range of the telegraph wires. Both sides destroyed telegraph lines and also tapped them to try to decipher the messages of their opponents.

The American Civil War also encouraged submarine development. Up to 20 working submarines were built by both sides during the war; however, most were undocumented. The most noteworthy from the period are the Union’s USS *Alligator* and the Confederacy’s *H. L. Hunley*. The *Alligator* was designed by French engineer Brutus de Villeroi (1794–1874) and was first launched on May 1, 1862. It included innovations like compressed and filtered air for its crew of 12. Just like the *Hunley*, the submarine was manually propelled. Unfortunately, *Alligator* was lost in a storm off Cape Hatteras on April 1, 1863, while being towed to Charleston for its first combat deployment. The *Hunley* had a test run in July 1863, that successfully attacked a coal flatboat in Mobile Bay. It was then shipped to Charleston and turned over to the Confederate Army.

A crew was assembled to make the first test dive, and one of the crewmen accidentally stepped on the lever that controlled the dive planes—causing the

Hunley to dive with the hatches open. Five of the crewmen drowned, and the *Hunley* ended up being recovered. The only successful attack came on February 17, 1864, against the USS *Housatonic*. The *Hunley* embedded its spar torpedo in the hull of the *Housatonic*, and as the submarine backed away from the ship, the torpedo detonated. The *Housatonic* sank in five minutes, and the *Hunley* sank to the bottom, not to rise until August 8, 2000. Although the USS *Alligator* and the *H. L. Hunley* made no great impact during the Civil War, they set the precedent for future generations of subs. The submarine was used widely during both World War I and World War II with great success.

During American Civil War, the railroads were second only to waterways when it came to transportation of troops and supplies. During the war, soldiers, material, and food were routinely transported by rail along with civilians and the raw materials necessary to keep the war effort progressing. Because the railroads supplied the units that were on campaign, they often became military objectives. One of the main factors in the eventual domination of the railways by the Union was the industrial power of the North, which was more industrialized than the South in part because the South relied on a slave-based labor force to create an agricultural economy.

The importance of the railroad appeared in the first major battle of the Civil War at the first Battle of Bull Run on July 21, 1861. A large and unprepared Union Army under the command of General McDowell moved south out of Washington, D.C., toward the rail center of Manassas, Virginia. A smaller and equally unprepared Southern force under the command of General P. G. T. Beauregard blocked this advance when Generals Joseph Johnson and Thomas J. (Stonewall) Jackson arrived from the Shenandoah Valley with their armies, using a rail line to speed their arrival at the front. This was the first significant use of a railroad in moving troops to battle, and it was extremely successful.

Union forces made it a priority to destroy railroads as they took the war through Mississippi, South Carolina, and Georgia. The destruction of the Confederate railways prevented easy transportation of troops to the front lines. Many of the Confederate railroads were captured and used by the Union to supply Grant’s

beleaguered, half-starved troops, and this allowed them to gain victory in the Battle of Chickamauga and Chattanooga. Later toward the close of the war, during the siege of Richmond and Petersburg—separated by only 25 miles—Grant provisioned his troops from an enormous rail depot at City Point. This rail junction proved useful in that the Union Army would have needed to rely on wagons and horses to supply it. Without the use of this important rail system, it was possible that the sieges could have failed and ultimately led Grant to release his stranglehold on the Confederacy.

The Pacific Railway Act of 1862 promoted the construction of the Transcontinental Railroad in the United States by authorizing bonds and grants of land to the different railroad companies involved. Lincoln signed this law because it helped in the construction of railroad and telegraph lines from the Missouri River to the Pacific Ocean. The act also secured the government's ability to use these same lines for postal, military, and other purposes. The act placed all employees and officers under military authority and was the precedent for the U.S. Railway Administration of World War I and government influence on railroads in World War II. During the Civil War, there were approximately 36,000 miles of track compared to today's 250,000 miles. The train systems throughout the United States are still relied upon to ship goods, people, military equipment, and more.

Scott Russell

See also Civil War Medicine; Civil War Nursing; Morse Code; Railroads; Repeating Rifle; Telegraph; Torpedo; Walker, Mary; Western Union Telegraph Company; *Vol. 1, Sec. 2: Steamboat*

Further Reading

- Bilby, Joseph G. 1996. *Civil War Firearms: Their Historical Background and Tactical Use* Cambridge, MA: De Capo Press.
- Bowers, Paul 1999. *The Garrett Enigma and the Early Submarine Pioneers*. Ramsey, UK: Airlife.
- Coggins, Jack. 2004. *Arms and Equipment of the Civil War*. New York: Courier Dover.
- Compton-Hall, Richard. 1983. *Submarine Boats: The Beginnings of Underwater Warfare*. Miami, FL: Windward.

Gillett, Mary C. 1987. *The Army Medical Department, 1818–1865*. Washington, D.C.: U.S. Government Printing Office.

Green-Lewis, Jennifer. 1996. *Framing the Victorians: Photography and the Culture of Realism*. Ithaca, NY: Cornell University Press.

Maxwell, William Quentin. 1956. *Lincoln's Fifth Wheel: The Political History of the U.S. Sanitary Commission* New York: Longmans & Green.

Peres, Michael R. 2007. *The Focal Encyclopedia of Photography: Digital Imaging, Theory and Applications, History, and Science*. New York: Focal Press.

Rutkow, Ira M. 2005. *Bleeding Blue and Gray: Civil War Surgery and the Evolution of American Medicine*. New York: Random House.

Mitchell, Maria (1818–1889)

Maria Mitchell was the first American astronomer to discover a “telescopic” comet—a comet too far away to see with the naked eye but detectable with a telescope. For her achievement, she was rewarded with a gold medal by the king of Denmark, became the first female member of the American Academy of Arts and Sciences, and later became a professor of Vassar College, one of the first exclusively all-women colleges in America.

Maria Mitchell was born on Nantucket Island, Massachusetts, in 1818. Her father, William Mitchell, was an accomplished amateur astronomer and encouraged her education, especially in math and science. At 18, she began work as a librarian at the Nantucket Atheneum by day, but at night, she would “sweep” the skies with her father for celestial objects in a small observatory he built.

On October 1, 1847, the 29-year-old Mitchell discovered a comet through her telescope. Not only was she the first American to discover a comet, but it was the first one detected with only a telescope. Even more impressive, she found it with only a tiny, two-inch telescope—demonstrating her skills as an astronomer to identify objects in the night sky. Many years before, the king of Denmark had offered a prize to whomever could find such a comet. While several astronomers spotted the comet, it was ruled that Mitchell was the

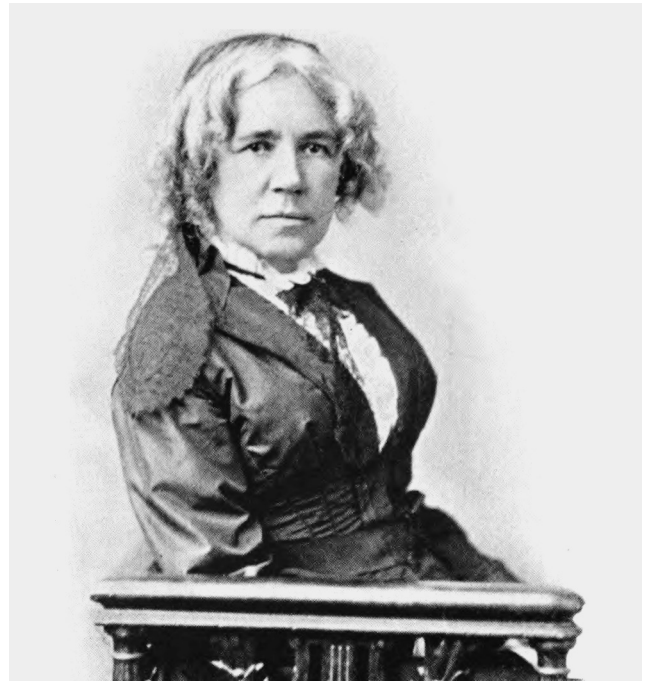
first to find it, and so she was awarded the gold medal for her achievement.

Nineteenth-century women's rights activists in Boston were proud of Mitchell, and with the support of several activists, including botanist Elizabeth Agassiz and publisher Elizabeth Peabody, Mitchell was elected into the American Academy of Arts and Sciences in 1848. She was the first woman to become a member and would be the only one for 100 years. She was also elected into the American Association for the Advancement of Science, which had recently formed and is today the publisher of the prestigious *Science* journal.

Mitchell returned to her life in Nantucket as a librarian, but the U.S. Coastal Survey paid her to sweep the skies now. Her task was to help develop weather forecasting and to measure and compute distances. People who did this became known as “computers.”

In 1865, she accepted a teaching position at Vassar College in Poughkeepsie, New York, one of the first colleges for women in the United States, though she was the only female professor out of the nine initially employed. With her father, she operated a 12-inch telescope at the school's observatory—the third largest in the country—and lectured her students at night with it. In a time when most colleges simply educated their students, Mitchell conducted original research with them; she brought them along to measure the 1869 total eclipse of the sun in Burlington, Iowa, and again in 1878 near Denver, Colorado. She also invented a device to take pictures of the sun, and her original engraved photograph plates were rediscovered in 1997. Notable inventors of the day, including Samuel F. B. Morse, corresponded with her.

As she aged, she became much more involved with politics and women's suffrage. Leading up to the Civil War, she swore never to wear cotton grown by slaves. At Vassar, she hosted “dome parties” in her observatory to discuss politics with her students and other activists and suffragists. Mitchell also led the creation of the American Association for the Advancement of Women (later renamed the American Association of University Women) and served as its president in 1873. Her list of friends included the likes of Elizabeth Cady Stanton, Susan B. Anthony, Elizabeth Blackwell, and many other activists.



As the first professional female astronomer in the United States, Maria Mitchell inspired countless young women to study science. Though relatively unknown today, her discovery of a new comet in 1847 made her internationally famous. (Kendall, Phebe Mitchell (compiler). *Maria Mitchell: Life, Letters, and Journals*. Boston: Lee and Shepard Publishers, 1896)

She retired and left Vassar in 1888, much to the dismay of her beloved students and in spite of the generous offer from the school to keep her residence and continue her research. She moved in with one of her sisters in Lynn, Massachusetts, and lived there until her death a year later from a brain disease. She was inducted to the Hall of Fame of Great Americans at New York University in 1905 and again into the National Women's Hall of Fame in Seneca Falls, New York, in 1994. When astronomers mapped the surface of the moon, they named a crater after her.

Elliott Popel

See also Vol. 1, Sec. 2: Blackwell, Elizabeth

Further Reading

Bergland, Rene. 2008. *Maria Mitchell and the Sexing of Science: An Astronomer Among American Romantics*. New York: Beacon Press.

Morse, Samuel F. B. (1791–1872)

Samuel Finley Breese Morse was the inventor of the telegraph as well as an outstanding American artist in the first half of the 19th century. Indeed, while Morse's artwork, especially his painting, earned him much praise, it was his invention of the telegraph, coupled with his role in developing the Morse code, that not only had a revolutionary impact on the United States in the decades before the Civil War but also played an important role in the conduct of the war itself.

Samuel F. B. Morse was born on April 27, 1791, in Charlestown, Massachusetts, the oldest child of Jedidiah Morse, a minister, and his wife, the former Elizabeth Breese. He attended Phillips Academy in Andover, Massachusetts, before going on to Yale College—from which he graduated in 1810 with a middling record but a deep interest in both art and electricity, the latter based upon a series of lectures he had attended. After his graduation from Yale, Morse, with grudging parental approval—his father, initially insisting that he pursue a trade, had arranged an apprenticeship with a local book publisher—traveled to Europe to pursue his art, studying at the Royal Academy of Arts in London. He adopted the European style for his painting, especially the renditions that highlighted historical events and personalities against bright colors. During his time abroad, Morse achieved some minor artistic success, and in 1815, he returned to the United States, still intent upon pursuing his painting career. Morse set up a base of operation in New Haven, Connecticut, although he traveled throughout New England and the Northeast and even ventured into South Carolina, seeking commissions. He achieved moderate success, receiving commissions to paint former president John Adams and President James Monroe as well as a number of other wealthy merchants and political figures. In addition to the portraits, he also painted a series of works that depicted the workings of the government. While they were not much appreciated at the time, they later decorated the halls of Congress and, like his portraits, they gained greater appreciation with time.

On September 29, 1818, Samuel Morse married the former Lucretia Walker. Together they had three

children, a girl and two boys. She died on February 7, 1825. Over two decades later, on August 10, 1848, Morse remarried, this time to the former Sarah Elizabeth Griswold, with whom he had four more children: three sons and a daughter.

In 1825, after the death of his first wife, he moved to New York City, where he assumed the presidency of the newly formed New York Drawing Association. The following year, he was a founder and the first president (a post he held for the next 19 years) of the National Academy of Design, an organization seeking to increase the nation's respect for its painters. In 1827, he helped launch the *New York Journal of Commerce* while also publishing *Academics of Art*.

In 1832, his longtime continuing interest in electricity led him to begin developing the idea of an electric telegraph after overhearing a conversation about the newly discovered electromagnet. While Morse believed his idea was original, in fact, the concept had been proposed as early as 1800, but the artist-turned-inventor pursued it nevertheless, making his first working model around 1835. Throughout this period, he continued to pursue his art and was also teaching at the University of the City of New York (later New York University). He also dabbled a bit in politics, running as an anti-Catholic and anti-immigrant candidate for mayor in 1836—and again in 1841. However, despite these other diversions, by 1837 he was focused on the development of his telegraph, teaming up with a colleague at the university, chemist Leonard Gale, and his friend, Alfred Vail. In 1838, Morse and Vail developed the system of dots and dashes that would become Morse code, but they were unable to convince Congress to undertake the construction of a telegraph line. Turning their attention to Europe, they sought the construction of a telegraph line on that continent, but that effort too was rebuffed. While his former partners abandoned the project, Morse continued his efforts to make a telegraph network a reality. Finally, in 1843, Congress gave Morse sufficient financial support to construct the nation's first telegraph line—one that went from Baltimore to the nation's capital. Completed in 1844, on May 24, Morse sent the first message: "What hath God wrought."

With telegraph communication a reality, Morse was soon the focus of a flood of legal claims from his

former partners and competing inventors over the rights to the invention and the inevitable profits that would flow from its development. These battles culminated in an 1854 decision by the U.S. Supreme Court that established Morse's patent rights. Meanwhile, as telegraph lines spread across the United States and Europe, Morse's wealth and fame also grew, and the one-time itinerant painter bought an estate, Locust Grove, overlooking the Hudson River near Poughkeepsie, New York. There he built a mansion designed in the style of an Italian villa. The site became the family's summer home, a retreat from their New York City residence.

The wealthy Morse spent his last years as an active philanthropist. He helped found and fund Vassar College in Poughkeepsie and also served on the college's board of trustees. He also gave generously to his alma mater, Yale, while a variety of churches, theological seminaries, and Bible societies also benefited from his generosity. So too did assorted missions and temperance societies, as well as the many struggling artists whose efforts he helped support.

With his 81st birthday approaching, Samuel F. B. Morse died on April 2, 1872, in New York City. He is buried in Green-Wood Cemetery in Brooklyn, New York.

William H. Pruden III

See also Morse Code; Printing Telegraph; *Vol. 2, Sec. 1*: American Telephone and Telegraph Company (AT&T)

Further Reading

Mabee, Carleton. 2000. *The American Leonardo: A Life of Samuel F. B. Morse*. New York: Purple Mountain Press.

Morse Code

Although nowadays the Morse code has come to be largely restricted to amateur communications and radio aficionados, for over a century, it was the most widely used system for transmitting communications. Thanks to it, text information could be easily and effectively conveyed regardless of distance.

The Morse code makes use of signals of different duration in order to transmit information. There are short signals, called "dots," and longer signals called

"dashes." A given character is a unique combination of dots and dashes, each dash having a three-dot duration. Every dash or dot is followed by a silence with the duration of a dot. Also, each letter is followed by a silence with the same duration as a dash, while every word is followed by a seven-dot silence.

The Morse code was named after its inventor, Samuel Finley Breese Morse (1791–1872). A Yale graduate, Morse's real passion was art, which his father at first discouraged. Eventually, his father relented, and Morse traveled to England to pursue an artistic career. However, Morse's creativity also found an outlet in designing and inventing and, along with his brother Sidney, he created a machine to cut marble. The brothers also got three patents for water pumps.

But the invention for which he would become world famous and make his name a byword for communication would not materialize until later in his life. Developing a system that could quickly transmit information over long distances was an issue that touched Morse very deeply. In 1825, his wife had died in New Haven, Connecticut, while he was away in Washington, D.C. However, a letter bearing the news did not reach him until a week later, when the funeral had already taken place.

Morse's interest in electricity dated from 1827, but he first thought of an electromagnetic telegraph in 1832 while traveling from Europe to the United States. He conceived the idea of an electrical current that could transmit information by means of a wire. It would not be until 1836, though, that he succeeded in bringing his idea to fruition. Morse worked closely with science professor Leonard Gale, making use of Joseph Henry's previous invention based on William Sturgeon's electromagnet. At first, Morse faced years of poverty and even derision, as a failed public demonstration made of him the butt of many jokes. In 1837, Alfred Vail attended a display of Morse's invention and was attracted to the idea. Vail's father agreed to finance Morse and host the project in his factory in exchange for his son's participation. In 1843, the American government gave Morse a grant to pursue his research. He used the funds to set up a telegraph line between Baltimore and Washington. On May 24, 1844, he transmitted the first message—"What hath God wrought," a biblical quotation from Numbers

23:23, which had been chosen by a minister's daughter.

The widespread popularity of the telegraph made Morse a well-known and wealthy man, although it also brought him its share of problems. Among these, the most serious involved accusations of plagiarism and intellectual theft. In 1837, the U.S. Supreme Court ruled that Morse reached the most perfect result for public and practical use.

The International Morse Code is a variation on the original code invented by Vail and Morse in 1835. Morse first imagined the code as consisting of a combination of numbers, with each unique combination assigned to a word. The first changes were introduced by German Friedrich Clemens Gerke in 1848. Standardized at the International Telegraphy Congress in Paris in 1865, it is known as International Morse Code or "the continental code" in contrast to the Morse code used in the United States and Canada and known as American Morse or "railroad code."

Of the most famous uses of the Morse code is "SOS," the distress signal. First used in 1905 by the German government, although popular belief attributes the SOS signal to an acronym for "save our ship" or "save our souls," it stands for no message. The Morse code proved to be vital during the Second World War, with some modifications to attempt to conceal messages. The advantage of using Morse code is that even in poor conditions, it can be comprehensible. Not only was the code used in telegraphic communication but also in radio systems, aviation, and across undersea cables.

Morse code was in use for maritime communication until 1999, when the Global Maritime Distress Safety System replaced it. The last official use of the Morse code in the United States was on July 12, 1999. The last message transmitted was "What hath God wrought."

M. Carmen Gomez-Galisteo

See also Telegraph

Further Reading

Mabee, Carlton. 2000. *The American Leonardo: A Life of Samuel F. B. Morse*. Fleischmanns, NY: Purple Mountain Press.

Silverman, Kenneth. 2004. *Lightning Man: The Accursed Life of Samuel F. B. Morse*. Cambridge, MA: Da Capo Press.

National Academy of Sciences (NAS)

The National Academy of Sciences (NAS) is a society of scientists, scholars, engineers, and other distinguished researchers. The organization was founded on March 3, 1863.

In the midst of the Civil War (1861–1865), the U.S. Congress created the National Academy of Science (NAS), composed of 50 original members. The NAS partnered with the National Academy of Engineering and the National Academy of Medicine to act as an advisory council to the president of the United States and help protect the public through research and by creating new standards for and advancements of safety in each respective field. Today, the National Academy of Sciences includes members from all over the country and supports the work of national institutes and laboratories. The NAS gives scholarships and awards to members with outstanding work to help support their ongoing research. It is not about the importance of any one person or a particular discovery or work but rather to support scientists and researchers who strive to improve society.

Of the almost 3,000 NAS members, approximately 200 have been awarded Nobel Prizes. This award is arguably the single most prestigious that anyone who contributes notably to society can receive—but even just being nominated to join NAS is a remarkable honor in itself, because the society accepts only the most elite contributors. For example, Frederick Sanger, a biochemistry researcher, helped discovered how to sequence mRNA and DNA. His work led to two Nobel Prizes in chemistry. His major breakthrough became the foundation of identifying genes that correlate to specific diseases as well as gene therapy, revolutionizing the way the medical field approaches a problem. Due in part to Sanger's work, we can customize medicine uniquely for an individual's genes.

Another National Academy member, James Tiedje, was the president of the American Society for Microbiology from 2004 to 2005; his research has been based on analytical experiments on the microbiology in soils necessary to sustain life. His tests were later used to test the hypothesis that life can be sustained on Mars.

Other notable contributors include Robert Oppenheimer, the "father of the atomic bomb," Stephen

Hawking for his work in theoretical astronomy that help us better understand the dynamics of the solar system, and Michael Goddard for his work in the development of genomic selection, which revolutionized the agricultural and livestock industries.

To become a member of the NAS, one must be nominated by an existing member; there is no application process. A scholar must be recognized as distinguished in his or her area of research, going through a rigorous process in which existing members closely review the nominee's publications and/or scientific data. The NAS judges whether or not the material is impactful and extraordinary enough to the scientific community to consider the prospective nominee an expert in his or her field. The number of new members elected every year is limited to 84 U.S. resident citizens and 21 foreign residents annually, with elections held each April. Currently, the NAS has roughly 2,300 native members and 460 foreign members, each of whom has contributed to the advancement of science.

Rosanne Welch

See also *Vol. 2, Sec. 1*: National Institutes of Health (NIH); *Vol. 2, Sec. 3*: Oppenheimer, J. Robert; *Vol. 3, Sec. 3*: Hawking, Stephen; Hubble Space Telescope; Human Genome Project; Mars Rover Series

Further Reading

Institute of Medicine, National Academy of Sciences, Committee on Revising Science and Creationism. 2008. "A View from the National Academy of Sciences." *Science, Evolution, and Creationism*. Washington, D.C.: National Academies Press.

Institute of Medicine, National Academy of Sciences, and National Academy of Engineering. 1989. *Science and Technology in the Academic Enterprise: Status, Trends, and Issues*. Washington, D.C.: The National Academies Press. <https://doi.org/10.17226/1468>.

Pais, Abraham. 2006. *J. Robert Oppenheimer: A Life*. New York: Oxford University Press

Nightingale Plan

The Nightingale plan, a model of how health-conscious hospitals should set up their wards, was named after the Englishwoman Florence Nightingale (1820–1910),

who served as a nurse in the Crimean War (1853–1856). Afterward, she founded the first secular school for nursing in the world in London. She is credited with having helped to advance the knowledge of proper hygiene and treatment in hospitals and for setting about the training of professional nurses. News of her work inspired nurses in the American Civil War and the female volunteers of the U.S. Sanitary Commission, who put Nightingale's plans into action in that conflict. American women also used Nightingale's writings as the basis for the professionalization of nursing and the transformation of nursing into a profession for women.

During the early 19th century, germ theory and basic hygienic practices were largely unknown to most physicians. There was understanding that overcrowding in hospitals and other areas could cause illness to spread, but that was seen as a result of impurities in the air, not of viruses or harmful bacteria. Water and food-borne diseases had not yet been fully understood or identified. Even Nightingale did not think that diseases could spread from contact; however, she did see that certain environmental factors could be detrimental to the health of those recovering from wounds and illnesses.

In 19th-century England, there were several breakouts of cholera and other epidemics that occurred in workhouses, boarding institutions, and other establishments that held large numbers of destitute people, including children. One institute in Tooting experienced a severe outbreak of cholera in the year 1849, where a minimum of 200 poor children died. An inquest later revealed that the outbreak had been a result of the children's poor diet and overcrowding. Most shocking for the British population was the high number of deaths caused by infection in the hospital in Scutari—located in what is now Istanbul—during the Crimean War. The barracks lacked nurses, nutritious food, clean water, laundry or spare clothing, a kitchen for proper cooking, and appropriate tools or amenities to take care of the sick and wounded. The reality of the soldiers' pitiful conditions eventually motivated the army to call out for aid. Nightingale and her nurses answered the call.

The Nightingale nurses were not the only ones who worked with the infirm. Long before nurses were professionally trained and disciplined, religious groups such as the Catholic Sisters of Mercy and the Church of England Sisters had reached out to help

with the sickly and dying wherever aid was required. After the Crimean War, Nightingale established a nursing school with the monetary gifts she received.

During the American Civil War, some infirmaries were taken care of by personal friends of Nightingale and other women who had studied her ideas of sanitation and nursing. Dorothea Dix, as the superintendent of army nurses, certainly understood and promoted the Nightingale plan in her crusade to organize nurses and provide soldiers with adequate battlefield health care. Clara Barton, who founded the Red Cross, also knew something of the Nightingale plan, though her work on the battlefield was often in conditions so rough that good hygienic practices were impossible. In the early 1900s, several nations joined in the Red Cross movement, and in 1909, the parties agreed on a resolution that honored Nightingale and her work as the starting point from which the Red Cross's activities had stemmed.

The mid-19th century was marked by humanitarian and architectural concerns in regard to public health centers. Nightingale's work during the Crimean War inspired her to write pieces about improving the structure of hospital wards, including providing enough space in them to prevent impurities from filling up the air. The Nightingale ward plans were long, narrow blocks without high ceilings but with tall windows along both sides of the rooms at regular intervals to allow fresh air to continually move throughout the wards. Between each pair of windows was space for a single bed. While the plans were named after Nightingale, the idea for them was not hers alone. Nonetheless, her writing on nursing and hospital construction played an important role in American women's history.

Therese Torres

See also Civil War Nursing

Further Reading

Gill, Gillian Catherine. 2004. *Nightingales: The Extraordinary Upbringing and Curious Life of Miss Florence Nightingale*. New York: Random House.

Nightingale, Florence. 1860. *Notes on Nursing: What It Is and What It Is Not*. New York: D. Appleton and Company.

North, Simeon (1765–1852)

Simeon North was a farmer and gun manufacturer credited with developing a machine that moved factory tool production a step closer to interchangeable parts: the milling machine.

North was born in Berlin, Connecticut, in 1765. He was a farmer from a wealthy family. Adjacent to his farm was a mill on a brook. He bought that property in 1795 so he could manufacture scythes at the mill.

Tool manufacture at the time was done by hand. Each tool was individually crafted, so parts were not identical. A craftsman made each piece and then assembled the tool. North's tools were known for high quality.

He was asked to make pistols, which were more complicated than farm tools. Their parts had to fit precisely, or the guns would not fire. The quality of North's crafted pistols resulted in a U.S. government contract in 1799 for 500 single-shot horse pistols. Horse pistols were flintlock guns that officers fired while riding horseback. North had one year to fill the contract. The 1799 contract was followed by another in 1800 for 1,500 pistols, with two years to deliver the guns. North received government contracts for the next 52 years.

North searched for ways to increase sales volume while maintaining quality. Individually crafted gun parts were not always identical, so a broken part could be impossible to replace, rendering a gun unusable. North and others worked to produce parts that were identical in size and shape so that if a gun part broke, it could be replaced and the gun would function again.

North received a government contract in 1813 to manufacture 20,000 pistols to be delivered in five years. A second factory was built in Middletown, Connecticut, to complete the large order. This contract was the first that stated that North's pistols would have interchangeable parts. The parts would be measured to a standard, uniform size.

A milling machine could produce such parts. North is credited with inventing a milling machine around 1816 that cut metal in a specified pattern or shape with exact dimensions. Parts were then checked with gauges to ensure that each part was identical in size and shape.

North's milling machine parts were the closest to achieving interchangeability at the time, but not 100 percent of the parts were interchangeable. Some still had to be filed down by workers to complete a gun assembly.

North began manufacturing rifles in 1823 and continued to produce quality guns for the rest of his life. He died in 1852. He is remembered as an innovator whose machine advanced the goal of interchangeable parts for many types of other machines.

Linda Briley-Webb

See also Interchangeable Gun Parts

Further Reading

Hounshell, David. 1984. *From the American System to Mass Production, 1800–1932*. Baltimore: The Johns Hopkins University Press.

Karwatka, Dennis. 1999. *Technology's Past*. Vol. 2, *More Heroes of Invention and Innovation*. Ann Arbor, MI: Prakken.

Muir, Diana. 2000. *Reflections in Bullough's Pond*. Hanover, NH: University Press of New England.

Nursing. See Civil War Nursing

Omnibus System

"Omnibus" refers to a passenger-carrying vehicle that is pulled by a horse. In the 1800s, omnibus systems were developed throughout Europe and America.

Public transportation vehicles were first introduced by French inventor Blaise Pascal in the 1600s. He proposed the idea of facilities for public transportation in Paris, and it was financed by the local nobility, which issued the construction of carriages that could potentially hold up to eight passengers. In 1662, the carriages became operational and charged a small fare. The idea was popular initially, but people at the time rode them for amusement rather than for practical daily transportation. As a result, the service ceased. Toward the end of the 1700s, cities and roads were developed to a point that allowed for the rise of the omnibus system. In the 18th century, horses and wagons had been the main method of transportation,

pulling small wagons of food and goods over land. Eventually, the idea of public transportation was picked up again in the 19th century.

In 1823, Stanislas Baudry introduced a vehicle that ran from the Nantes Central Square of Nantes to Richebourg for bathing guests; however, he realized that it could be more practical as local transportation. He commissioned an English coach maker named George Shillibeer to design a vehicle that was stable and large enough to carry many passengers. In 1828, the first omnibus service began, running between la Madeleine and la Bastille. The ride took about 15 minutes and cost about 25 centimes. Within six months, about 2.5 million passengers had used the service. The omnibus system would continue to expand throughout Paris, London, and even the United States.

The first omnibus system in the United States began in New York City in 1830. Horse-drawn carriages were then the main method of transportation; John Stephenson built the first horse-drawn railcar in 1832. He became the first president of the New York and Harlem Railroad's Fourth Avenue Line. Over the next 30 years, the omnibus system grew, but the carriers could not accommodate that many passengers, and fares were relatively high. The development of paved roads helped smooth the ride of the omnibus wheels and made trips faster. Horse-drawn streetcars became the main method of transportation in the 1850s. Those who lived in suburbs or residential areas utilized the horsecar system to commute to downtown. The system spread to cities such as San Francisco, California, in the 1860s and Los Angeles and Oakland in the 1880s.

The omnibus went through a number of improvements throughout the years. For many years, the bus remained a single-deck vehicle that seated about two or three people; later, there was a second row that accommodated another two or three people. In 1851, London staged the Great Exhibition, where producers of omnibuses bolted in a plank along the curved roofs of their vehicles to allow more passengers to sit.

Horse cars had some drawbacks. For instance, they did not meet the demand for cheaper and reliable urban transportation. Also, overworked horses could drop dead from exhaustion. Horse feces and urine caused sanitation problems in American cities on a scale now unimaginable. Plus, horses could only work

part of the day, so horses would have to be changed as the hours went by. Last, horses could not pull cars up steep hills, making public transportation a challenge in hilly cities like San Francisco.

The omnibus system led to other innovations in transportation. Tram systems, which consisted of horse-drawn passenger tramways, eventually led to the development of cable cars in the 1880s. These moved along steel rail lines and were eventually powered by electricity and moved continuously. In the 1880s, the Chicago Railway converted to cable cars and eventually to electric trolleys by the 1890s.

For the next 30 years, a variety of transportation sources were available in American cities and towns. Streetcars, horse-drawn carts, and carriages all shared the same roads. There were also elevated tracks, called “els,” that were built about 25 feet above the ground and used mainly by commuters into the city. The late 20th century, however, saw the removal of many city streetcar systems, though some still remain today.

Brian Yu

See also Electric Street Railway; Railroads

Further Reading

- Moffet, Glendon L. 1997. *Uptown, Downtown: Horsecars and Trolley Cars, Urban Transportation in Kingston, New York, 1866–1930*. New York: Purple Mountain Press.
- Nord, David Paul. 2009. *A History of the Book in America*. Vol. 5. Chapel Hill, NC: UNC Book Press.
- White, John H., Jr. 1974. *Horsecars, Cable Cars and Omnibuses*. New York: Dover.

Papermaking Machine

Paper has been around for centuries, and despite today’s technological advancements that have promised paperless offices, paper is still relevant today. But it would not be as available to the public had it not been for many industrial innovations. The papermaking machine had quite a history in Europe before it first made its way to the United States. Thomas Gilpin’s papermaking machine was not only the first in the United States but the first in the world that included the use of a cylindrical mold. It appeared in 1817.

Gilpin and his brother, Joshua, founded Brandywine Paper Mills after producing their first paper in 1787. Its location in Delaware could not have been better, since the required materials were easily obtained nearby or shipped via Brandywine Creek. The supply of fresh water was crucial in the process of papermaking. A year after the brothers manufactured their first paper, they met Nathan Sellers, from whom they bought paper molds.

Joshua visited Europe to further expand his knowledge of the machine-papermaking process. The manager of Brandywine Paper Mills, Lawrence Greatrake, acquired a drawing of the Fourdrinier paper machine done by one of its creators, John Hall. The Fourdrinier machine was one of the two more advanced papermaking machines in Europe. The second machine, which John Dickinson patented in 1809, was based on the use of a cylinder to create a continuous sheet of paper. Though he did not share any documentation of his machine, Dickinson gave Greatrake permission to draw it, because he was confident that his work could not be duplicated, especially since most of the mechanical details were unseen.

However, Greatrake succeeded in collecting what Gilpin needed to incorporate in his new papermaking machine, which greatly took after both the Fourdrinier and Dickinson machines. Gilpin earned his patent in 1817, and the machines that influenced his model would not be introduced to the United States until at least a decade later.

Dannela Azul Valencia

See also Vol. 1, Sec. 2: Milling Machine; Waltham-Lowell Textile System

Further Reading

- Hancock, Harold B., and Norman B. Wilkinson. 1957. “The Gilpins and Their Endless Papermaking Machine.” *The Pennsylvania Magazine of History and Biography* 81, no. 4: 391–405.
- Sandy Historical Society. 2013. “Paper Making Machines: A Brief History & How They Work.” <http://sandyhistorical.org/2013/10/16/paper-making-machines-a-brief-history-how-they-work/>, accessed August 22, 2018.

Pencil Eraser

Modern pencils come topped with erasers and are one of the most familiar objects in American daily life. Hymen Lipman (1817–1893) patented the first pencil-and-eraser combination in 1858. Historians believe that the first wood-encased pencils date to about the 1500s, while erasers were developed by Edward Nairne in 1770. However, Lipman was the first person to think of combining both objects into one instrument, patenting a wood-encased pencil that contained lead on one end and an eraser on the other in 1858. In 1862, he sold the rights to his patent to Joseph Reckendorfer for \$100,000.

The Supreme Court of the United States invalidated the patent in 1875, however, concluding that Lipman had only put two existing objects together rather than invented something new. The ruling meant that pencil manufacturers were free to modify Lipman's initial design. The Faber Pencil Company soon developed a pencil with an eraser attached to the top—the design widely used today.

Alberta M. Miranda

See also *Vol. 2, Sec. 1: Paper Clip*

Further Reading

Kennedy, Pagan. 2013. "Who Made That Built-In Eraser?" *New York Times Magazine*, September 13. <http://www.nytimes.com/2013/09/15/magazine/who-made-that-built-in-eraser.html>, accessed August 22, 2018.

Petroski, Henry. 1990. *The Pencil: A History of Design and Circumstance*. New York: Knopf.

Pepper (and Salt) Shaker

The two most common ingredients used to season any dish are salt and pepper. Many years ago, salt and pepper had a value on the same level as currency in some parts of the world.

John Landis Mason, who was also the creator of the mason jar, invented the salt shaker in 1858. His design included the application of a screw top lid. Though his idea was innovative, in addition to its

perforated cap design, it did not achieve much success or attention until the 1920s. The design of the product was not the issue, but rather the clumping quality of the salt, which prevented it from passing through the holes. Many others followed Mason with their designs, including one for a single shaker that contained both salt and pepper and another for two similar-looking shakers but one with a special marking for the pepper.

Dannela Azul Valencia

See also Mason Jar

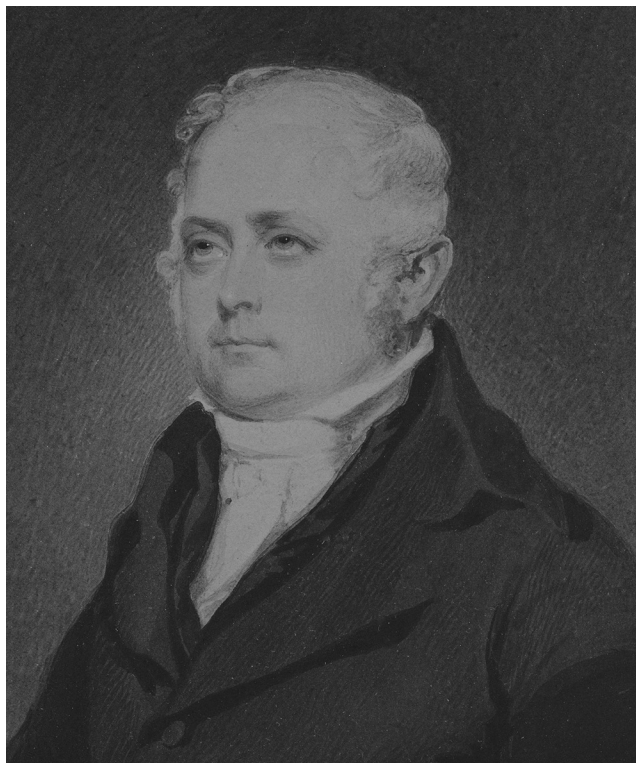
Further Reading

Butler, Stephanie. 2013. "Off the Spice Rack: The Story of Pepper." *Hungry History*, January 17. <http://www.history.com/news/hungry-history/off-the-spice-rack-the-story-of-pepper>, accessed August 22, 2018.

Perkins, Jacob (1766–1849)

Jacob Perkins was a mechanical engineer, inventor, and physicist who was known for a variety of useful inventions, most significantly the first ice-making refrigerator. Perkins was born in Newburyport, Massachusetts, on July 9, 1766. He left school at 12 years old and became an apprentice to a goldsmith named Davis. After the goldsmith died, Perkins continued manufacturing gold beads, and he perfected a method for creating gold-plated shoe buckles at 15 years of age. When he was 21, he became known for making dies for striking copper coins.

In 1790, he invented a machine for cutting nails with implanted heads. This invention greatly simplified the nail manufacturing process. He operated a nail-making business, but a lawsuit forced him to shut it down. Due to this setback, Perkins's next plan was to improve the way that banknotes were engraved by using steel plates instead of copper ones—a process that made counterfeiting more difficult. He traveled to England in 1818 to supply local banks with his plates in hopes of finding investors to fund his engraving technology. He established a London plate-manufacturing business as a result of his efforts. At the same time, Perkins worked on steam engines and technology for steam guns.



Jacob Perkins invented an early refrigerator, as well as innovating in gun and steam technology. He also improved the engraving process for bank notes by using steel plates, rather than copper. (Science & Society Picture Library/Getty Images)

In 1805, Oliver Evans was the first person to design an ice-making machine, but he never finished his project. In 1834, Perkins modified Evans's design and finished building the first ice machine known as the refrigerator. It used closed-cycle vapor compression. His work was inspired by the refrigeration principles developed by Benjamin Franklin and others.

Perkins's refrigeration machine was not safe for domestic use, however, because it relied on dangerous substances like ammonia and ether in its cooling process. These gases were used to absorb heat and lower the temperatures of nearby objects. Perkins effected this by using a compressor to exert pressure on the dangerous gases to convert them to liquid that then moved through the machine's coils to absorb heat. As the pressurized liquids absorbed heat, they returned to their gaseous form before returning to the compressor for repeated use.

In November 11, 1790, Hannah Greenleaf of Newbury married Perkins; they had nine children.

Their second son, Angier March Perkins, was also an engineer. Angier Perkins worked for most of his career in the United Kingdom and was eager in inventing new technologies for central heating. He partnered with his father and eventually took over the family business. Loftus Perkins, a grandson, also became an engineer, and he devoted his time to improving refrigeration and heating, as well as further developing the steam engine. Jacob Perkins retired in 1843 and died in London, England, on July 30, 1849. He is buried in Kensal Green Cemetery, London.

Johnson D. Ton

See also *Vol. 1, Sec. 1*: Franklin, Benjamin; *Vol. 1, Sec. 2*: Evans, Oliver; Steam Engine

Further Reading

- Cowan, Ruth S. 1985. *More Work for Mother: The Ironies of Household Technology from the Open Hearth to the Microwave*. New York: Basic Books.
- Peavitt, Helen. 2017. *Refrigerator: The Story of Cool in the Kitchen*. London: Reaktion Books.
- Perkins, Thomas A. 2016. *Jacob Perkins of Wells, Maine and His Descendants, 1583–1936*. London: Facsimile.

Platform Scale

The platform scale, which weighs large or heavy objects by use of an automatic system of levers and adjustable weights, was invented by Thaddeus Fairbanks in 1830. In 1824, he started E & T Fairbanks, a company with his brother Erastus. Their association with a failing hemp dressing business shined a light on another issue: they had noted that the existing method of weighing things was flawed. It required a series of steps, including suspending the material to be weighed, which was difficult with larger and heavier objects.

After many iterations, Thaddeus's invention was finally built in 1830. His apparatus did not require unloading or suspension; only the rolling of a wagon that the material was placed in onto the scale. He was awarded a patent for the platform scale in June 21, 1831. He and his brother would later receive others

under differing categories, such as “weighing heavy bodies.”

Dannela Azul Valencia

See also Compact Iron Stove; Polished Steel Plow

Further Reading

“Fairbanks, Morse & Company.” 2006. *Midcontinent*, April 9. <https://www.midcontinent.org/rollingstock/builders/fairbanks.htm>, accessed August 22, 2018.

Polished Steel Plow

A blacksmith by trade but a genius by reputation, John Deere will be remembered for inventing the first successful polished steel plow in 1837. It revolutionized farming by breaking up the thick, clay-like soil and root mats created by the indigenous prairie grasses of the American Midwest. This allowed the region to earn the title, “the nation’s breadbasket.” The plow led to the establishment of Deere & Company, one of the largest agricultural and construction equipment manufacturers in the world.

While the new plow may have been John Deere’s idea, the inspiration belonged in part to his father, William, a merchant tailor, who polished his sewing needles to pierce fabric smoothly. When John Deere left his home in Vermont in 1836 to seek his fortune in Illinois, he took his blacksmithing skills with him, and also the memory of his father and his shiny needles.

Farming in the Midwest was different from anything Deere and other East Coast transplants had ever experienced. Unlike the sandy New England soil, the Midwest’s was dark, moist, and sticky, and it clung to cast-iron plows, adding hours to the planting process. Deere, who had a blacksmith business in Grand Detour, Illinois, was convinced that a plow that was highly polished and properly shaped could scour itself as it cut furrows. In 1837, he created such a plow using a broken saw blade. That first plow led to another and another, and by 1841, he was building 100 per year and realized that he would need the backing of a partner to expand the operation.

Leonard Andrus joined the effort, and together they produced plows in Grand Detour until 1848,

when they parted company and Deere moved the business to Moline, Illinois. The larger city, perched on the Mississippi River, was also a rail hub, which meant that the raw materials needed to build the plows could be acquired both quickly and cheaply. The new location also meant a new factory, which was built with new partners: Robert Tate and John Gould. A year after arriving in Moline, the company was turning out 200 plows a month. Tate’s and Gould’s positions were bought out in 1853, and Charles Deere, John’s son, came into the business. Over the next five years, wagons and corn planters were added to the inventory, and that diversification may have played a role in seeing the company through the financial panic that swept the United States in 1858. It did require John Deere to sell a controlling interest in the company to his son, however, who then managed the daily operations. But John Deere remained active in the company, serving as president until his death in 1886.

Today, the Deere Corporation’s distinctive green-and-yellow color scheme adorns thousands of tractors, combines, and construction machines around the world.

John A. Morello

See also Deere, John and Deere and Company; *Vol. 1, Sec. 2: Steam Tractor*

Further Reading

Dahlstrom, Neil, and Jeremy Dahlstrom. 2005. *The John Deere Story: A Biography of Plowmakers John & Charles Deere*. Dekalb: Northern Illinois University Press.

Printing

You wouldn’t be reading this book if printing hadn’t been invented. From woodblock to moveable type to digital printers, printing technology makes life a joy and a job. Printing allows people to communicate. It lets us remember what we’ve heard, said, or seen. History can be written down so that people know what happened and who was there. Information can be shared and business transactions logged; so can details, important and not so important. Printing has improved how we communicate.

Printing has changed over time, although all printing consists of something to write with, an ink, and something to write on. Before the Common Era, Egyptians were writing on papyrus. Fiber taken from the papyrus plant was made into thin sheets that were overlapped and then pressed so they would stick together to form a single sheet. Scrolls could be made from sheets into different lengths as needed. Brushes made from reeds were used to write on the papyrus. Ink was made by mixing carbon black, gum arabic, and water. Papyrus is still in existence today; many ancient examples show drawings of people, their way of life, and events long gone by.

Since papyrus was not widely available and somewhat expensive, people looked for other materials to write on. In countries around the Mediterranean long ago, untanned and tanned animal skins were used to produce parchment. The skin was scraped, soaked, cleaned, stretched, and dried. The resulting writing surface was smooth to write on. Unlike dried animal skin treated to become leather, parchment absorbs moisture and is smooth. Hollow reeds with one end cut to a point were used to write with. Water mixed with gum arabic and a pigment made up the ink.

Woodblocks were used in China almost 2,000 years ago to print images and words onto textiles. Printing was also done on silk, bones, and bamboo. By the seventh century, printing was done on paper, although not of the best quality. Some paper was made from linen or cotton; because it was soft, it was difficult to use and preserve. But over time, paper quality was improved with the addition of wood pulp to the cotton. China continued to improve the quality of paper. The Chinese used ink made from black pigment from pine-wood combined with animal glue and something to maintain consistency, such as egg white or camphor.

Block printing was used in the Middle East for prayer books in the ninth century. Small woodcut cards were produced in Europe in the 14th century, especially of religious images. These were printed much like stamps, just as we could do today. Any text on the card was added by hand, so making these images was a slow process.

The invention of movable type created a faster means of printing books. Johann Gutenberg (1398–1468) revolutionized the printing process with the

invention of movable type. Essentially, instead of using a single large stamp for printing the whole image of a page, he designed a series of small stamps, each representing a single letter of the alphabet or number, to print the text of a book. Each stamp had to be exactly the same size and shape so that they could easily be removed if needed without disrupting the rest of the page to be printed. These individual stamps would be assembled line by line within a frame to print a page of text. Mistakes could be corrected by replacing the individual stamp in error—but proofreading was essential. When the page was perfect, one copy or multiple copies could be produced. Afterward, the letters would be disassembled and the next page of text could be created, reusing the same individual letter stamps.

The individual letter stamps had to be sturdy to be used in printing after printing; they were made of metal—usually tin or lead. When text was printed, some areas were left blank so that images or decorations could be added by hand.

Gutenberg's machine pressed letters down uniformly and with more force than a person could press down a stamp, created a more uniform print overall. His was not an easy machine to build. Developing and improving it took him 20 years.

The quality of the ink used with these stamps was important. Water-based ink did not work well with the metal stamps. When they were pressed against the paper, the ink had to not run or smear, and it had to be the right consistency to produce a readable letter that didn't blur on the paper and distort a word. Gutenberg used an oil-based ink with carbon, copper, lead, and other pigments for color.

His faster printing process would have been of no use, however, with nothing to print on. But cheap paper was available in quantity by the time Gutenberg's press was ready to begin.

Gutenberg began printing Bibles in 1454. The text was two columns per page, with 42 lines on each page, and it was in Latin. Between 200 and 300 Bibles were produced, with least 30 printed on vellum (calf skin) and the rest on paper. Each had 1,282 pages. Gutenberg had produced the first printed book.

Unfortunately, Gutenberg went into debt to produce his invention and lost all his tools, the printing

presses, and his shop to those he owed money to. They published the Gutenberg Bible while he died in debt.

But Gutenberg's invention had changed the production of books forever. Classical manuscripts were being mass-produced by the early 16th century, and the price of books decreased while the number of books increased.

Every European country had a printing press within 15 years of Gutenberg's invention. Martin Luther and others used it to print pamphlets to distribute to followers. Ideas could be disseminated to more people because of the printing press, and more books were printed in the next 50 years than had ever been printed before. The first newspaper opened in Germany in 1609.

Printers began making improvements to the printing press to make it sturdier. Iron and brass replaced wood. Levers were introduced to replace the screw mechanism that had been used to press the letter stamps onto the paper. The lever allowed more uniform tightening and more uniform-looking print. But the printing press was still a labor-intensive machine.

William Nicholson patented "A Machine or Instrument on a New Construction for the Purpose of Printing on Paper, Linen, Cotton, Woolen and other Articles in a more Neat, Cheap and Accurate Manner than is effect by the Machines now in use" in 1790. His machine had multiple rotating cylinders. On was a cylinder of rotating letters to be printed, another held the sheet of paper to be printed on, and another spread ink on the form. However, the intricate machine was never built due to lack of money.

Soon, though, printing became a business that many could enter, including Benjamin Franklin, who made his fortune as a printer before moving into politics during and after the American Revolution.

Inventors continued to make improvements and changes to the printing press. Friedrich Koenig invented the double-sided press in 1814. Around 1843, Richard M. Hoe invented and built the first practical rotary press to print on long rolls of continuous paper. The design was updated and improved by William Bullock, who patented a steam-powered press fed by rolls of paper in 1863. His press could print 12,000 newspapers an hour.

Typewriters were developed in the 1870s, and within 15 years were used in many business offices. The machine used moveable-type letters, symbols, and numbers. Printing could now be done on an individual basis as needed.

Printing has become even more technical today. Inkjet printers were invented in the mid-20th century. Inkjets rely on small droplets of ink sprayed on paper to recreate digital images. Laser printers use digital printing as well. A laser scans over a drum to produce the image to be printed using powdered ink.

Handwritten text has largely been replaced by mechanical printing. Labor-intensive printers have been replaced by machines. Computers with keyboards have replaced typewriters. Printing still requires something to write with and the something to write on—at least for now.

Linda Briley-Webb

See also *Vol. 1, Sec. 1*: Franklin, Benjamin

Further Reading

- Asimov, Isaac. 1982. *Asimov's Biographical Encyclopedia of Science & Technology. The Lives & Achievements of 1510 Great Scientists from Ancient Times to the Present*. Garden City, NY: Doubleday.
- Black, Jeremy. 1999. *World History*. Bath, UK: Parragon.
- Houston, Keith. 2016. *The Book: A Cover-to-Cover Exploration of the Most Powerful Object of Our Time*. New York: W. W. Norton.

Printing Telegraph

The printing telegraph was developed as an alternative to the Morse telegraph with the goal to eliminate the coding and decoding of each symbol as a set of dots and dashes. Samuel Morse's method required trained personnel on both receiving and transmitting ends, which severely limited its speed. As an alternative, Alfred Vail, Morse's partner, proposed in 1837 that the printing head should utilize a wheel with all 24 letters of the alphabet. The wheel would then be moved by a spring mechanism similar to the one used in clocks,

and an electromagnetic key would stop the wheel at a particular position according to the received letter, requiring precise synchronization between the sending and receiving parts. According to an agreement between Vail and Morse, Vail abandoned his idea and gave all credit to Morse.

The first practical printing telegraph was invented by Royal E. House, who obtained a patent for it in November 1848. However, in 1847, in a letter to the *Philadelphia Ledger*, Samuel Morse claimed that he already invented a telegraph capable of printing letters of the alphabet. The investigations of and arguments over the originality of House's design in comparison to Morse's patent from 1837 took almost two years, and in the end, House's telegraph was classified as a "signal and printing telegraph," while Morse's was a "writing telegraph." As a result, the effective date for House's patent was changed to April 18, 1846.

As proposed, the House printing telegraph consisted of both a transmitter, called a composer machine, and a receiver/printer. The composer machine and printer were moved by a crank connected to a balance wheel to ensure smooth motion. In a subsequent version, a cylinder with pressurized air was used to move the parts. On the composer side, the printing telegraph used a keyboard similar to a piano keyboard with 28 keys. Under the keys was a cylinder with spiral-mounted pins. When a key was pressed, the cylinder and attached tooth wheel would stop at the position corresponding to a particular letter, punctuation mark, or space. When the cylinder was moved from one letter to another, a sequence of contacts and interruptions was given so that the wheel on the receiving part was in the exact same position as the one on the sender's side. When the wheel stopped on the receiver's side, the corresponding letter was marked on paper.

The House telegraph was first used successfully in 1849 between New York and Philadelphia. Although it was a much more complex instrument than the Morse telegraph, it offered greater flexibility and a notably higher speed. Unfortunately, it was also expensive, very complex, difficult to manufacture, and was not designed for (and performed poorly on) long lines. Despite the fact that a significant number of House systems were installed on the East Coast of the United

States between 1849 and 1860, the apparatus was gradually replaced by other machines—in many cases by David Hughes's telegraph, which was invented in 1855. In 1857, the newly formed American Telegraph Company purchased Hughes's telegraph and gave it to George M. Phelps for improvement. Phelps had already opened a shop in Troy, New York, called House's Printing Telegraph Instrument Manufacturer, and in 1856, the American Telegraph Company made Phelps superintendent for production of the recently purchased Hughes telegraph. In 1866, the Western Union Company, which manufactured House telegraphs, purchased the American Telegraph Company and made Phelps responsible for the mechanical department—first in Troy, then Williamsburg, and ultimately New York City. Using his experience with both the House and Hughes printing telegraph systems, Phelps developed an electromotor printing telegraph capable of operating over long lines.

Developments and improvements of the printing telegraph continued over the next few decades, including the Essick page-printing telegraph, which was introduced in 1894 by the Union Telegraph and News Company of New York as a system designed to work private lines and railway service. The Essick system was advertised as capable of being attached to any telegraph line while using less power compared to the Morse telegraph. In addition, the Essick telegraph could work on lines of any length and was much smaller in size.

Stefka Tzanova

See also Morse, Samuel F. B.; Morse Code; *Vol. 2, Sec. 1: American Telephone and Telegraph Company (AT&T)*

Further Reading

- Hochfelder, David. 2012. *The Telegraph in America, 1832–1920*. Baltimore: John Hopkins University Press.
- Standage, Tom. 2014. *The Victorian Internet: The Remarkable Story of the Telegraph and the Nineteenth Century's On-line Pioneers*. New York: Bloomsbury.

Pullman, George Mortimer (1831–1897)

George Pullman was a pioneering businessman in the 19th century. He is best known for the development of the Pullman Sleeping Car, an innovation that offered comparative luxury for nation's long-distance rail travelers.

George Pullman was born on March 3, 1831, in Brockton, New York, the third of nine children born to James Lewis Pullman and the former Emily Caroline Blunt. Pullman had little formal education, having quit school after the fourth grade to work in a local general store owned by his mother's uncle. In 1848, Pullman moved to Albion, New York, joining his father, who had started a business moving buildings out of the way of the advancing Erie Canal. After his father died in 1853, George took over the business. His big break soon came when, working on the setup of Chicago's new sewage system, he was able to lift the buildings so efficiently that businesses were able to operate uninterrupted. With the resulting income, in partnership with friend and state senator Benjamin Field, he started a sleeper car company in 1857.

Pullman's Palace Car, a luxury version of an idea dating back to the 1830s, represented a radical departure in comfort and attractiveness. While previously the goal had been to minimize discomfort, Pullman sought to entice people to experience the trip in style. Initial public response was overwhelmingly positive, but the company's future was secured after Pullman offered the use of a car to Mrs. Mary Lincoln when she accompanied her slain husband's body back to Springfield, Illinois, for burial.

Leasing the cars to the railroads rather than selling them, the company prospered, with approximately 2,000 cars leased out and a net worth estimated at about \$62 million at its peak. In 1867, after Field ended their partnership, Pullman formed the Pullman Palace Sleeping Car Company, of which he was president and general manager. With the new company, Pullman sought to consolidate operations and get an ever greater control of all aspects of his business. In 1880, Pullman bought a 4,000-acre tract near Lake Calumet just south of Chicago. There he built a new

factory and established a community consisting of 1,300 housing units as well as shopping areas, churches, parks, a hotel, a library, and a man-made lake, all of which Pullman controlled.

The dangers of the arrangement became clear when in response to the recession of 1893, Pullman cut workers' wages but refused to lower any costs related to living in the town. The predictably disgruntled workforce resorted to a massive strike, which, supported by the American Railway Union, became a national event and was settled only when President Grover Cleveland dispatched troops to end it. A national commission established to investigate the landmark strike laid much of the blame at the feet of Pullman and the paternalism involved in his operation of a town that the report called "un-American." Indeed, following up, in 1898, the Illinois Supreme Court forced the company to divest its ownership interest in the town, which was later annexed by Chicago.

By that time, George Pullman had died of a heart attack on October 19, 1897. After a private funeral, he was buried in a specially secured structure in Chicago's Graceland Cemetery.

William H. Pruden III

See also Railroads; *Vol. 2, Sec. 1: Railroad Sleeping Car and Pullman Car*

Further Reading

Leyendecker, Liston Edgington. 1992. *Palace Car Prince: A Biography of George Mortimer Pullman*. Boulder: University Press of Colorado.

"People & Events: George Pullman (1831–1897)." *PBS: The American Experience*. http://www.pbs.org/wgbh/amex/chicago/peopleevents/p_pullman.html, accessed August 22, 2018.

"The Pullman Company." <http://www.pullman-museum.org/theCompany/>, accessed August 22, 2018.

Railroad T-Rail and Tie

Many of the basic design features of modern railroad track were first used in 1831 on the Camden and Amboy Railroad, a short line in New Jersey. The track

design, including an all-iron rail with a T-shaped profile, was designed by Robert L. Stevens (1787–1856), the president and chief engineer of the line.

Most of the earliest railroads in the United States had been built using strap rail, which consisted of a solid wooden plank laid across the ties (the ties—called “sleepers” in Great Britain—are the crosspieces between the rails, which provide a foundation for the track and aid in keeping the rails in gauge). The wooden plank was topped with a thin strap of iron, and the wheels of the locomotives and cars rode on this iron strap. The iron strap was usually about five-eighths of an inch thick, about two and a half inches wide, and made in strips 18 feet long. This rail was suitable only for lightweight equipment carrying relatively small loads, but most of the locomotives and cars in use were much smaller and lighter than what would become standard a few years later.

There were problems with strap rail, even with the lightweight equipment in use. The thin strip of iron tended to wear quickly. A somewhat rare but dangerous problem was what were called “snakeheads”—the iron strap would sometimes break and curl back like a snake rearing to strike. This bent piece of rail could break through the bottom of railcars and do serious damage to cargo or harm to passengers. Despite these problems, about 3,000 miles of strap rail was laid on the earliest U.S. railroads.

Robert Stevens considered himself primarily a naval architect, and he and his father, John Stevens, were heavily involved in the development of steamboats in the United States. The Stevens family was the major backer of the Camden and Amboy Railroad, which was incorporated in 1830. While Robert was made president and chief engineer of the railroad, his brother Edwin A. Stevens, was also an officer of the company.

When the railroad’s executives decided not to use strap rail, they found that no foundries in the United States could make the type of rail that they hoped to use. Robert was sent to England to buy rail, and while on the journey, he carved several different wooden patterns of the type of rail he envisioned, finally settling on the T-rail design. Stevens had trouble finding a foundry in Great Britain willing to make his rail, but it was finally produced by an ironworks in Dowlais,

Wales, owned by Sir John Guest, a member of Parliament. The first shipment of rails arrived in Philadelphia in May 1831.

Stevens also ordered six-inch spikes with a hooked head; this type of spike has become known as a “dog spike,” and its use on the Camden and Amboy marked its introduction to the United States. The Camden and Amboy Railroad first intended to lay its rail on stone ties, but when the supply of these ties ran short, it turned to wooden ties. The system of wooden ties lying in a bed of gravel ballast with the T-rails secured to the tie with hook-headed spikes was all part of Stevens’s innovative design on his railroad.

Railroad builders consider the design of the T-rail to be very practical, and though it has been slightly modified over the years, it has never been surpassed. The head of the rail has a large mass to support the weight of railroad cars and locomotives and can take a substantial amount of wear before needing replacement. The vertical portion of the rail, called the “stem” or “web,” connects the head to the wide, flat base that provides stability. T-rail has been used by railroads throughout the world. An English designer, Charles B. Vignoles, developed a similar design in 1836, and this type of rail is often referred to as “Vignoles rail” in Europe.

Mark S. Joy

See also *Vol. 1, Sec. 2: Steamboat*

Further Reading

“All Aboard: Railroads and New Jersey, 1812–1980.” n.d. http://www.libraries.rutgers.edu/rul/exhibits/nj_railroads/njrr.php#case:1, accessed August 22, 2018.

Grant, H. Roger. 2005. *The Railroad: The Life Story of a Technology*. Westport, CT: Greenwood Press.

Railroads

Railroads revolutionized the transport of goods across the United States. In the 19th century, as more and more people populated the West, railroads became the reliable method to travel back and forth. Railroads

also allowed farmers to get their crops to market relatively quickly and inexpensively. Railroads are one of the landmark developments of the 19th-century Industrial Revolution, both as products of other technological revolutions like steam power and steel production and as a driver of westward expansion, industrialization, and urbanization.

The British pioneered rail lines and steam power in the first decades of the 19th century. A number of Americans investigated the British rail system and worked to bring the innovation to the United States. The oldest railroad in the United States is the Baltimore and Ohio (B & O) Railroad, completed on February 28, 1827. Baltimore proved more eager than other major American cities in part because the city had no canal. A railway based in Charleston, South Carolina, soon followed. The South Carolina Canal and Railroad Company featured the country's first commercially available steam locomotive, the *Best Friend of Charleston*.

Railroads played a crucial role in the American Civil War, so much so that historians generally cite them as one of the top reasons that the Union won the war. First, Northern states had industrialized and not only had a considerable number of railroad companies and thousands of miles of rails, but they had the means to produce additional rails, locomotives, and railcars. Southern states, particularly those that became part of the Confederate States of America, tended to be agricultural rather than industrial, a by-product of the region's commitment to black slavery. When the war began, the Union could move troops and goods much more quickly and efficiently than could the Confederacy. Also, as the Union Army encroached on an area, it would destroy Southern rail lines, crippling the Confederacy. Because the war was fought mainly in Confederate territory, the Union's ability to destroy rail lines became one of the crucial factors in the Union's ultimate victory.

The Transcontinental Railroad system, built to connect the eastern United States with the West, joined the Union Pacific Railroad and Central Pacific Railroad. The two companies began at separate locations and joined up between them. One company went west from Omaha, Nebraska, while the other lay tracks from Sacramento, California. The companies eventually met

at Promontory, Utah, on the date of completion in 1869, marking the first time that a railroad connected the East of the United States to the West.

The first transcontinental railroad had legal troubles, and both companies found ways to benefit monetarily (each company received 12,800 acres of land and \$48,000 in bonds from the government for each mile of track it set) while competing to be the first to get farthest across the nation. At the helms of each company were people who felt that being the first to revolutionize the industry would serve them well in the future. At the Sacramento starting point were four like-minded and creative businessmen—Charles Crocker, Leland Stanford, Collis Huntington, and Mark Hopkins—who were ready to make corrupt choices to exploit loopholes and make the most money possible by milking the government of resources. At the Omaha starting point was an educated man named Dr. Thomas Durant, who had received full authority over the project illegally. By doing this, he could guarantee profits.

As the two companies worked to quickly lay down tracks and rake in profits, each had troubles. The Union Pacific Railroad, while moving westward, was faced with attacks from the Native Americans who were losing land to the railroad and fearful of the progress that the white man was making. As people moved westward, they created settlements known as part of the “Wild West.” The Central Pacific Railroad, with Charles Crocker in charge of construction, began to hire Chinese workers in 1865 who had already been on the West Coast, having arrived in time for the California Gold Rush. The Chinese workers were tireless laborers who would do anything to make their way in the United States and assimilate.

The Union Pacific Railroad began to pull away from the Central Pacific Railroad in terms of ground covered by railroad tracks in the summer of 1867. In the race for each to get ahead of the other company, the final stretch became a gruesome one, so the government stepped in with Ulysses S. Grant, who was president at the time, and withheld funding in early 1869 until the companies established decorum and a meeting point at Promontory Summit. They would eventually complete the railroad on May 10, 1869, by driving a final spike into the ground.

In the late 19th century, railroad companies consolidated to such an extent that the U.S. Congress responded with anti-monopoly legislation. Large railway companies like the Great Northern or the Southern Pacific created immense problems for farmers, who were forced to rely on a single company to get their goods to market. The so-called robber barons of the age—men like Cornelius Vanderbilt, Jay Gould, Collis Huntington, and Leland Stanford—made immense sums of money while pauperizing farmers, who were forced to pay high shipping rates or lose their crops. Railroad barons also benefited from federal and state government policies friendly to large corporations.

In the 20th century, as other transportation methods began to take over personal transportation (particularly automobiles), the railroad industry began to focus on commercial markets that moved goods from ports into the rest of the country. Also, as automakers tackled energy-efficient technology, so too did railroad companies, introducing diesel-electric locomotives to the rails. Finding an effective way to use the transport method while also saving money worked out well for the suppliers of goods and the people operating the railroad systems. Farmers and corporations would pay less for shipping costs, and fuel for the

railroad systems would make less of a hole in the operators' pockets.

Today, the railroad system in the United States is primarily a means of transporting goods from the ports and across the country, or from manufacturer warehouse points inland. In addition to shipping goods, railroads offer a means of cost-effective and scenic vacation or business travel.

Emma E. L. Burke

See also *Best Friend* Steam Engine; Steam Locomotive; *Vol. 1, Sec. 2: Canals*; Steam Engine; *Vol. 2, Sec. 1: Transcontinental Railroad*

Further Reading

- Solomon, Brian. 2014. *North American Railroads: The Illustrated Encyclopedia*. McGregor, MN: Voyageur.
- Wiatrowski, Claude A. 2012. *Railroads across North America: An Illustrated History*. Sarasota, FL: Crestline.
- Wilson, Jeff, ed. 2014. *The Historical Guide to North American Railroads*. Waukesha, WI: Kalmbach.
- Wolmar, Christian. 2013. *The Great Railroad Revolution: The History of Trains in America*. New York: PublicAffairs.

Primary Document: Pacific Railway Act (1862)

Enacted in July 1862 during the Civil War, the Pacific Railway Act allotted federal funds and land for the construction of a transcontinental railway. Such legislation had been strongly opposed by the Southern states prior to their secession.

CHAP. CXX.—An Act to aid in the Construction of a Railroad and Telegraph Line from the Missouri River to the Pacific Ocean, and to secure to the Government the Use of the same for Postal, Military, and Other Purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That Walter S. Burgess, William P. Blodget, Benjamin H. Cheever, Charles Fosdick Fletcher, of Rhode Island; Augustus Brewster, Henry

P. Haven, Cornelius S. Bushnell, Henry Hammond, of Connecticut; Isaac Sherman, Dean Richmond, Royal Phelps, William H. Ferry, Henry A. Paddock, Lewis J. Stancliff, Charles A. Secor, Samuel R. Campbell, Alfred E. Tilton, John Anderson, Azariah Boody, John S. Kennedy, H. Carver, Joseph Field, Benjamin F. Camp, Orville W. Childs, Alexander J. Bergen, Ben. Holliday, D. N. Barney, S. De Witt Bloodgood, William H. Grant, Thomas W. Olcott, Samuel B. Ruggles, James B. Wilson, of New York; Ephraim Marsh, Charles M. Harker, of New Jersey; John Edgar Thompson, Benjamin Haywood, Joseph H. Scranton, Joseph Harrison, George W. Cass, John H. Bryant, Daniel J. Morell, Thomas M. Howe, William F. Johnson, Robert Finney, John A. Green, E. R. Myre, Charles F. Wells, junior, of Pennsylvania; Noah L. Wilson,

Amasa Stone, William H. Clement, S. S. L'Hommedieu, John Brough, William Dennison, Jacob Blickinsderfer, of Ohio; William M. McPherson, R. W. Wells, Willard P. Hall, Armstrong Beatty, John Corby, of Missouri; S. J. Hensley, Peter Donahue, C. P. Huntington, T. D. Judah, James Bailey, James T. Ryan, Charles Hosmer, Charles Marsh, D. O. Mills, Samuel Bell, Louis McLalle, George W. Mowe, Charles McLaughlin, Timothy Dame, John R. Robinson, of California; John Atchison and John D. Winters, of the Territory of Nevada; John D. Campbell, R. N. Rice, Charles A. Trowbridge, and Ransom Gardner, Charles W. Penny, Charles T. Gorham, William McConnell, of Michigan; William F. Coolbaugh, Lucius H. Langworthy, Hugh T. Reid, Hoyt Sherman, Lyman Cook, Samuel R. Curtis, Lewis A. Thomas, Platt Smith, of Iowa; William B. Ogden, Charles G. Hammond, Henry Farnum, Amos C. Babcock, W. Seldon Gale, Nehemiah Bushnell and Lorenzo Bull, of Illinois; William H. Swift, Samuel T. Dana, John Bertram, Franklin S. Stevens, Edward R. Tinker, of Massachusetts; Franklin Gorin, Laban J. Bradford, and John T. Levis, of Kentucky; James Dunning, John M. Wood, Edwin Noyes, Joseph Eaton, of Maine; Henry H. Baxter, George W. Collamer, Henry Keyes, Thomas H. Canfield, of Vermont; William S. Ladd, A. M. Berry, Benjamin F. Harding, of Oregon; William Bunn, junior, John Catlin, Levi Sterling, John Thompson, Elihu L. Phillips, Walter D. McIndoe, T. B. Stoddard, E. H. Brodhead, A. H. Virgin, of Wisconsin; Charles Paine, Thomas A. Morris, David C. Branham, Samuel Hanna, Jonas Votaw, Jesse L. Villiams, Isaac C. Elston, of Indiana; Thomas Swan, Chauncey Brooks, Edward Wilkins, of Maryland; Francis R. E. Cornell, David Blakely, A. D. Seward, Henry A. Swift, Dwight Woodbury, John McKusick, John R. Jones, of Minnesota; Joseph A. Gilmore, Charles W. Woodman, of New Hampshire; W. H. Grimes, J. C. Stone, Chester Thomas, John Kerr, Werter R. Davis, Luther C. Challiss, Josiah Miller, of Kansas; Gilbert C. Monell and Augustus Kountz, T. M. Marquette, William H. Taylor, Alyin Saunders, of Nebraska; John Evans, of Colorado; together with commissioners to be appointed by the Secretary of the Interior, and all persons who shall or may be associated with them, and their successors, are hereby created and erected into a body corporate and politic in deed and in law,

by the name, style, and title of "The Union Pacific Railroad Company;" and by that name shall have perpetual succession, and shall be able to sue and to be sued, plead and be impleaded, defend and be defended, in all courts of law and equity within the United States, and may make and have a common seal; and the said corporation is hereby authorized and empowered to layout, locate, construct, furnish, maintain, and enjoy a continuous railroad and telegraph, with the appurtenances, from a point on the one hundredth meridian of longitude west from Greenwich, between the south margin of the valley of the Republican River and the north margin of the valley of the Platte River, in the Territory of Nebraska, to the western boundary of Nevada Territory, upon the route and terms hereinafter provided, and is hereby vested with all the powers, privileges, and immunities necessary to carry into effect the purposes of this act as herein set forth. The capital stock of said company shall consist of one hundred thousand shares of one thousand dollars each, which shall be subscribed for and held in not more than two hundred shares by any one person, and shall be transferable in such manner as the by-laws of said corporation shall provide. The persons hereinbefore named, together with those to be appointed by the Secretary of the Interior, are hereby constituted and appointed commissioners, and such body shall be called the Board of Commissioners of the Union Pacific Railroad and Telegraph Company, and twenty-five shall constitute a quorum for the transaction of business. The first meeting of said board shall be held at Chicago at such time as the commissioners from Illinois herein named shall appoint, not more than three nor less than one month after the passage of this act, notice of which shall be given by them to the other commissioners by depositing a call thereof in the post office at Chicago, post paid, to their address at least forty days before said meeting, and also by publishing said notice in one daily newspaper in each of the cities of Chicago and Saint Louis. Said board shall organize by the choice from its number of a president, secretary, and treasurer, and they shall require from said treasurer such bonds as may be deemed proper, and may from time to time increase the amount thereof as they may deem proper. It shall be the duty of said board of commissioners to open

books, or cause books to be opened, at such times and in such principal cities in the United States as they or a quorum of them shall determine, to receive subscriptions to the capital stock of said corporation, and a cash payment of ten per centum on all subscriptions, and to receipt therefor. So soon as two thousand shares shall be in good faith subscribed for, and ten dollars per share actually paid into the treasury of the company, the said president and secretary of said board of commissioners shall appoint a time and place for the first meeting of the subscribers to the stock of said company, and shall give notice thereof in at least one newspaper in each State in which subscription books have been opened at least thirty days previous to the day of meeting, and such subscribers as shall attend the meeting so called, either in person or by proxy, shall then and there elect by ballot not less than thirteen directors for said corporation; and in such election each share of said capital shall entitle the owner thereof to one vote. The president and secretary of the board of commissioners shall act as inspectors of said election, and shall certify under their hands the names of the directors elected at said meeting; and the said commissioners, treasurer, and secretary shall then deliver over to said directors all the properties, subscription books and other books in their possession, and thereupon the duties of said commissioners, and the officers previously appointed by them shall cease and determine forever, and thereafter the stockholders shall constitute said body politic and corporate. At the time of the first and each triennial election of directors by the stockholders two additional directors shall be appointed by the President of the United States, who shall act with the body of directors, and to be denominated directors on the part of the government; any vacancy happening in the government directors at any time may be filled by the President of the United States. The directors to be appointed by the President shall not be stockholders in the Union Pacific Railroad Company. The directors so chosen shall, as soon as may be after their election, elect from their own number a president and vice-president, and shall also elect a treasurer and secretary. No person shall be a director in said company unless he shall be a bona fide owner of at least five shares of stock in the said company, except the two directors

to be appointed by the President as aforesaid. Said company, at any regular meeting of the stockholders called for that purpose, shall have power to make by-laws, rules, and regulations as they shall deem needful and proper, touching the disposition of the stock, property, estate, and effects of the company, not inconsistent herewith, the transfer of shares, the term of office, duties, and conduct of their officers and servants, and all matters whatsoever which may appertain to the concerns of said company; and the said board of directors shall have power to appoint such engineers, agents, and subordinates as may from time to time be necessary to carry into effect the object of this act, and to do all acts and things touching the location and construction of said road and telegraph. Said directors may require payment of subscriptions to the capital stock, after due notice, at such times and in such proportions as they shall deem necessary to complete the railroad and telegraph within the time in this act prescribed. Said president, vice-president, and directors shall hold their office for three years, and until their successors are duly elected and qualified, or for such less time as the by-laws of the corporation may prescribe; and a majority of said directors shall constitute a quorum for the transaction of business. The secretary and treasurer shall give such bonds, with such security, as the said board shall from time to time require, and shall hold their offices at the will and pleasure of the directors. Annual meetings of the stockholders of the said corporation, for the choice of officers (when they are to be chosen) and for the transaction of annual business, shall be holden at such time and place and upon such notice as may be prescribed in the by-laws.

SEC. 2. And be it further enacted, That the right of way through the public lands be, and the same is hereby, granted to said company for the construction of said railroad and telegraph line; and the right, power, and authority is hereby given to said company to take from the public lands adjacent to the line of said road, earth, stone, timber, and other materials for the construction thereof; said right of way is granted to said railroad to the extent of two hundred feet in width on each side of said railroad where it may pass over the public lands, including all

necessary grounds for stations, buildings, workshops, and depots, machine shops, switches, side tracks, turntables, and, water stations. The United States shall extinguish as rapidly as may be the Indian titles to all lands falling under the operation of this act and required for the said right of way and; grants herein-after made.

SEC 3. And be it further enacted, That there be, and is hereby, granted to the said company, for the purpose of aiding in the construction, of said railroad and telegraph line, and to secure the safe and speedy transportation of the mails, troops, munitions of war, and public stores thereon, every alternate section of public land, designated by odd numbers, to the amount of five alternate sections per mile on each side of said railroad, on the line thereof, and within the limits often miles on each side of said road, not sold, reserved, or otherwise disposed of by the United States, and to which a preemption or homestead claim may not have attached, at the time the line of said road is definitely fixed: Provided, That all mineral lands shall be excepted from the operation of this act; but where the same shall contain timber, the timber thereon is hereby granted to said company. And all such lands, so granted by this section, which shall not be sold or disposed of by said company within three years after the entire road shall have been completed, shall be subject to settlement and preemption, like other lands, at a price not exceeding one dollar and twenty-five cents per acre, to be paid to said company.

SEC. 4. And be it further enacted, That whenever said company shall have completed forty consecutive

miles of any portion of said railroad and telegraph line, ready for the service contemplated by this act, and supplied with all necessary drains, culverts, viaducts, crossings, sidings, bridges, turnouts, watering places, depots, equipments, furniture, and all other appurtenances of a first class railroad, the rails and all the other iron used in the construction and equipment of said road to be American manufacture of the best quality, the President of the United States shall appoint three commissioners to examine the same and report to him in relation thereto; and if it shall appear to him that forty consecutive miles of said railroad and telegraph line have been completed and equipped in all respects as required by this act, then, upon certificate of said commissioners to that effect, patents shall issue conveying the right and title to said lands to said company, on each side of the road as far as the same is completed, to the amount aforesaid; and patents shall in like manner issue as each forty miles of said railroad and telegraph line are completed, upon certificate of said commissioners. Any vacancies occurring in said board of commissioners by death, resignation, or otherwise, shall be filled by the President of the United States: Provided, however, That such commissioners shall be appointed by the President of the United States unless there shall be presented to him a statement, verified on oath by the president of said company, that such forty miles have been completed, in the manner required by this act, and setting forth with certainty the points where such forty miles begin and where the same end; which oath shall be taken before a judge of a court of record.

Source: *U.S. Statutes at Large*, 37th Congress, 2nd Session, 489–90. Library of Congress.

Ratchet Wrench

The most common type of socket wrench is the ratchet socket wrench, also known as a ratchet. A ratchet is a handheld metal tool that uses a ratcheting mechanism to tighten or loosen bolts and nuts, known generally as fasteners. The ratcheting mechanism allows for quick adjustment of these fasteners because the ratchet stays connected during adjustment. This speed is attributed to a lever that allows the user to switch between

loosening and tightening modes quickly and with ease. The ratchet has interchangeable sockets, which are usually hexagonal, to correctly fit the size of the fastener. The sockets are connected to the handle of the ratchet via a driver, which can come in various sizes. In general, the size of the driver and the amount of torque are directly proportional.

In the mid-1800s, *Scientific American* magazine opened a patent agency to encourage the development of new technology and ideas in the United States.

The best ideas that it received were then featured in the magazine as a reward. J. J. Richardson of Woodstock, Vermont, created the ratchet as part of this campaign. The idea was inspired by the old socket wrenches of the Middle Ages—those that were used as keys to wind up clocks. During that time, many of the sockets were square because of manufacturing limitations. As technology improved, however, hexagonal sockets became more popular. Although the socket wrench has been around for several centuries, the ratcheting socket wrench—combining the ratcheting mechanism with interchangeable sockets—was a novel idea. Richardson patented his new invention through the Scientific American Patent Agency in 1863, and an illustration of his ratchet was featured in *Scientific American* in 1864.

Richardson's invention became a necessity in every mechanic's toolbox. As a result, hexagonal heads and sockets have also gained popularity. With modern technology, it has become increasingly easier to mill, broach, and shape hexagonal pieces to replace the outdated square components of the earlier centuries. Drive fittings now come in four standard sizes: one-quarter inch, three-eighths inch, half inch, and three-quarters inch. These sizes are trade names; they are actually constructed using these rounded metric equivalents: 6.3 mm, 9.5 mm, 12.5 mm, and 19 mm. After Richardson constructed the original ratchet, many other similar tools have been invented.

The click-style torque wrench and flex-head ratchet are the most commonly used offspring of Richardson's ratchet. The click-style torque wrench clicks when a preset torque is achieved. This torque value is displayed digitally on the tool itself, or the tool slips off the fastener when the required torque value is reached. The flex-head ratchet has a swiveling head. The drive head rotates in opposite directions on a pivot near the back. There are many other types of ratchet wrenches, all inspired by the original. These ratchets vary by size, manufacturer, and other features.

Brenna Biggs

See also Eggbeater; Twist Drill

Further Reading

- Anonymous. "Improved Wrench." 1864. *Scientific American* 10, no. 16 (April): 248.
- Richardson, J. J. 1863. Improvement in Wrenches. U.S. Patent 38914.

Relay

The electromechanical relay was invented in 1835 by scientist Joseph Henry (1797–1878), a pioneer in electricity and magnetism. His relay was an electrical switch that used an electromagnet to open and close contacts in a circuit.

Relays consist of an iron bar tightly wrapped with a coil of wire (an electromagnet), a movable armature, and a set of electrical contacts. When electricity is applied to the wire, it creates a temporary magnetic field. Reversing the electric current changes the polarity of the magnetic field, and turning off the current collapses the magnetic field. The relay thus operates as an on-off switch.

It was not until the 1860s that Henry's invention became widespread—when it was incorporated into the telegraph and, later, the telephone. Relays were also used to construct Boolean logic circuits that could perform basic binary arithmetical operations. These circuits later formed the backbone of the first mechanical computers.

Karen S. Garvin

See also Coil Magnet/Electromagnet; Electric Doorbell; Henry, Joseph; Telegraph; *Vol. 2, Sec. 3: Telephone*

Further Reading

- Moyer, Albert E. 1997. *Joseph Henry: The Rise of an American Scientist*. Washington, D.C.: Smithsonian Institution Scholarly Press.
- Williams, Michael R. 1997. *A History of Computing Technology*. 2nd ed. New York: Wiley.

Repeating Rifle

Long-barrel guns have been used by hunters and soldiers for centuries. A gun with a long barrel that is pressed against the shooter's shoulder to fire is a rifle. Early rifles fired one shot at a time. It took decades of experimentation and hard work to design and manufacture a multiple-shot, or repeating, rifle.

Early muzzle-loaded gun barrels were smooth on the outside and inside. Gunpowder was necessary for ignition when firing a gun, and unburned powder

residue accumulated inside the barrel. A straight-groove rifle or cut inside the barrel decreased this residue buildup. Cutting a curved or spiral groove worked even better and had the added positive effects of increasing the shot's range and improving its balance and stability. Rifles were known for their accuracy.

Loading a gun was a multistep process. Gunpowder was poured down the barrel's muzzle, followed by a lead ball. A small amount of gunpowder was put in the flash pan. The gun's cock held a piece of sharp flint (this is a hard mineral) that sparked when hit. When the trigger was pulled, the flint sparked, igniting the gunpowder, and the lead ball was pushed down the gun's barrel by the force of the explosion. Then the next lead ball was loaded.

John Hancock Hall (1781–1841) invented a breechloading, single-shot rifle and patented it in 1811. Hall worked at the rifle works at the U.S. Armory at Harpers Ferry, Virginia (now West Virginia), where he improved the rifle's performance. Hall later patented a breechloading, single-shot rifle that used percussion-cap ammunition.

Percussion caps were an improvement. The cap was placed over a small raised area at the rear of the gun barrel. Pulling the gun's trigger released the hammer, which struck the cap and ignited the explosive material (held in a metal container that was closed at one end). This then ignited the gunpowder and pushed the bullet down the barrel.

The next step in rifle development would be from single shot to multiple shot, but progressing from one to the other required more than redesigning the gun. Ammunition needed to be more uniform and easier to load.

Walter Hunt patented his Rocket Ball ammunition in 1848. The Rocket Ball consisted of a hollow cartridge filled with gunpowder. The back or rear part of the cartridge was sealed with a cap that had a small open hole. Hunt designed a gun (called the Volitional Repeater—later, the Volcanic) that fired this ammunition. The gun's tube-shaped magazine was under the barrel. The shooter's finger pressed a spring-loaded lever to feed ammunition into the breech.

The following year, Lewis Jennings patented improvements to Hunt's rifle. This gun was manufactured at Robbins & Lawrence Company in Vermont. Horace Smith and D. B. Wesson bought Jennings's

patent in 1854 and improved the lever-action gun. They improved the ammunition by adding a fulminate-backed metal disk to the rear of the Rocket Ball cartridge. Since primer surrounded the rim of this cartridge, no percussion cap was needed. It ignited when struck anywhere along the rim. Smith and Wesson formed the Smith & Wesson Company in Connecticut, but they changed its name to Volcanic Repeating Arms Company in 1855.

An investor in Volcanic Repeating Arms was Oliver Winchester (1810–1881), a New York City businessman. Though Smith and Wesson left the company in 1857, it kept the rights to the gun and ammunition. Winchester, as majority stockholder and a vice president in the company, became president. Volcanic Repeating Arms was renamed the New Haven Arms Company. Former Robbins & Lawrence shop foreman Benjamin Tyler Henry (1821–1898) was hired as plant superintendent.

Henry was an experienced gunsmith. Henry developed a brass cartridge in 1859 that was longer than currently used lead cartridges, so it held more powder. The brass cartridge expanded upon firing and created a better seal between casing and breech. Henry developed a rifle to fire this ammunition and patented it in 1860.

The Henry rifle's magazine tube held 15 cartridges. To fire the rifle, the trigger guard lever was pushed down and forward to eject the spent or used casing out the top of the gun's breech, forcing a fresh cartridge into a lift mechanism and cocking the gun's hammer. The rifle was then ready to fire.

One disadvantage of the Henry rifle was that the end of the gun's magazine tube had to be unfastened to reload cartridges. A competing rifle, the Spencer, had a latch on the end of its rifle buttstock that was hinged so that the empty magazine tube could be removed and an already-loaded magazine put in place. Shooters carried a pouch with preloaded magazine tubes.

New Haven Arms Company's name was changed to Henry Repeating Rifle Company in 1865. Winchester remained president, and the following year, the company was renamed Winchester Repeating Arms Company.

The 1866 Model Winchester corrected some issues with the previous model. Since repeated firing caused the rifle barrel to heat up, a wooden piece was placed over the barrel so a shooter's hand would not be

burned when touching it. To make reloading easier, a rear spring-loaded mechanism was added. This model was manufactured for 32 years.

The Winchester Company produced many variations of guns. The Winchester Model 1873 rifle had an iron frame and the 1884 model a steel frame. The Model 1894 was the first sport rifle to exceed 1 million in sales. President Calvin Coolidge was given the millionth rifle produced in 1927, and President Dwight Eisenhower the 2-millionth rifle in 1953. Over 7 million have been manufactured.

Rifles and repeating rifles remain popular today, and Winchester Repeating Arms is still in operation.

Linda Briley-Webb

See also Colt, Samuel; Colt Revolver

Further Reading

Hounshell, David A. 1984. *From the American System to Mass Production, 1800–1932*. Baltimore: The Johns Hopkins University Press.

Pauly, Roger. 2004. *Firearms: The Life Story of a Technology*. Westport, CT: Greenwood Press.

Wexler, Bruce. 2015. *50 Guns That Changed America*. New York: Skyhorse.

Roller Skates

John Joseph Merlin is given credit for inventing the first roller skates in 1760. They were inline skates, not quad skates. Quad skates were invented in 1863 by James Leonard Plimpton. They have four wheels each in two side-by-side pairs, front and rear. The skates allowed the skater to turn or pivot by leaning to one side or the other. Soon, roller rinks were opened. The first roller rink opened in New York City in Plimpton's own furniture store. Another soon followed in Newport, Rhode Island, also involving Plimpton's support. The quad skate became the most popular style of skating for more than a century.

People continued working on improving the roller skate. In 1876 an Englishman, William Brown, patented a new design for the wheels of roller skates. Brown worked with Joseph Henry Hughes, the patent holder for a roller bearing for carriage wheels and



The roller-skating craze reached its peak in the 1920s with skating marathons or derbies. While young people loved roller skating, social conservatives disapproved. Some cities banned the sport from streets and sidewalks. (Library of Congress)

bicycles that included an adjustable system for the wheels. This allowed for both a fixed and a moving axle in the skates. This might have been the most important advance in roller skates and is the basis for the modern skateboard as well as modern skates. In 1876, the toe stop made its appearance. It allows the skater to stop by raising the back of the skate and resting the toe stop on the ice. By the 1880s, thousands of skates per week were being mass-produced. The adjustable skate screw was invented to adjust the skate over a shoe more easily.

In 1902, the modern inline skate appeared. Inline skates have anywhere from two to five wheels in a single line. Generally, recreational inline skates have a toe stop on the frame's rear. Inline skates resemble ice skates because they were developed to be a substitute for them. The original American patent for inline skates was issued in 1953 to Ernest Kahlert. These

skates were not commercially available until 1987 and were made by Rollerblade.

Roller skates appear to go through periodic booms. One such boom came with the birth of disco, with the marriage of disco and roller-skating. At its height in the late 1970s, over 4,000 disco roller-skating rinks were open, and roller disco movies were in fashion. Meanwhile, design and safety has continued to improve. In 1993, Rollerblade Inc. developed a safer and better way to brake Active Brake Technology (ABT). In this system, a fiberglass post was attached at one end to the top of the boot and at the other end to a rubber brake, which is hinged on the chassis at the back wheel. The skater must straighten one leg to stop, pushing the post into the brake so that it hits the ground. This is an improvement on the traditional technique of toe braking or even heel braking.

Given the number of contact sports that have come out of roller skating, increased safety is important. There is hockey played with roller skates instead of ice skates, racing, and—one of the more popular sports—roller derby. Roller derby grew out of the marathon racing of the 1930s, which was done around banked, indoor tracks. It is a contact sport played by two teams of five members and is dominated by women. Modern roller derby as we have come to know it is credited to Leo Seltzer and Damon Runyon. In the late 20th century, roller derby began to resemble professional wrestling, with show-business touches and scripted winners. In the 21st century, these touches were given up, and it returned to its grass roots.

Roller skates have come to be an important part of American recreation and sports. They continue to undergo improvements and to be popular as a form of entertainment and exercise.

Frank Salamone

See also *Vol. 2, Sec. 1: Velocipede*

Further Reading

Atwell, Margot. 2015. *Derby Life: A Crash Course in the Incredible Sport of Roller Derby*. Paperback. Brooklyn, NY: Gutpunch Press.

Bellis, Mary. 2017. "The History of Roller Skates." *ThoughtCo*, April 24. <https://www.thoughtco.com/history-of-roller-skates-1992385>, accessed August 22, 2018.

Rotary Hook (for Sewing Machines)

Allen Benjamin Wilson patented the rotary hook and bobbin for sewing machines, which eventually replaced a shuttle mechanism, in 1851. The purpose of a rotary hook is to open the needle's thread loop. In turn, the lockstitch was completed by a reciprocating bobbin that carried a second thread through the loop that the rotary hook had opened. A year later, Wilson replaced the reciprocating bobbin with a stationary one. These improvements led to a revolutionary change in sewing.

Allen Benjamin Wilson (1824–1888) was born in Willett, New York. He became a cabinetmaker, apprenticing at the age of 16. In 1847, he left New York State for Adrian, Michigan, to pursue that profession. After patenting sewing machine ideas, he joined forces with Nathaniel Wheeler, who was a partner in Warren and Woodruff in Watertown, Connecticut. Wilson moved there and continued to perfect his sewing machine.

Wilson used a commercial Wheeler and Wilson machine for obtaining his rotary hook patent. Wheeler and Wilson founded a new company to manufacture his revolutionary machine, and in 1856, the company moved to Bridgeport, Connecticut, where it became the most prominent and successful producer of sewing machines in the period.

Frank Salamone

See also Sewing Machine, Automated; Sewing Pattern

Further Reading

Yenne, Bill, and Morton Gross. 1993. *100 Inventions That Shaped World History: A Companion to 100 Events That Shaped World History*. New York: Bluewood Books.

Rucker Ambulance

The Rucker ambulance was designed by D. H. Rucker for use during the American Civil War. It was one of the most useful ambulances then because it could transport four patients at once. Rucker's ambulance saw heavy battlefield use, and it was also used after the war. Although different ambulance designs were

drawn up afterward, none could dethrone the Rucker as the most useful of the mid-19th century.

Before the Civil War, the U.S. military had no feasible means to transport the injured either during war-time or peace. The first ambulances were two-wheeled, horse-drawn wagons that could transport two to three people at a time. Prior to the Rucker ambulance were the Finley and the Coolidge, but they were not seen as field ready or suitable to transport wounded and injured. As the use of ambulances rose during war-time, more and more were designed.

The Rucker, like the other ambulances, was a four-wheeled, horse-drawn version most commonly used on battlefields. It could carry up to four patients. The rear had two seats with compartments that could be lowered to make additional space for stretchers to accommodate injured soldiers. The compartments were also ventilated when all the sides of the wagon were opened.

After the Civil War, the Rucker ambulance made its way into regular civilian life and was used until the introduction of the Terre Haute ambulance.

Fredy G. Mena

See also Civil War Medicine; Civil War Nursing; Hospital Transport Service, Women's Department; *Vol. 2, Sec 1: Military Technology* (Post-Civil War through World War I)

Further Reading

Bell, Ryan Corbett. 2012. *A History of the Ambulance*. Reprint ed. Jefferson, NC: McFarland.

Haller, John S., Jr. 2011. *Battlefield Medicine: A History of the Military Ambulance from the Napoleonic Wars through World War I*. Carbondale: Southern Illinois University Press.

Toler, Pamela D. 2017. *Heroines of Mercy Street: Real Nurses of the Civil War*. Boston: Back Bay Books.

Safety Pin

A safety pin is an object used in place of buttons, hooks, or zippers to fasten clothing. Inventor Walter Hunt, also responsible for building America's first sewing machine, twisted wire into the pin's

rudimentary shape and saw the possibilities. He coiled the wire into a spring at one end and a separate clasp and point at the other, which allowed the point of the wire to be forced by the spring into the clasp. He claimed that the clasp would keep fingers safe. For his work on the safety pin, Hunt was granted U.S. Patent 6,281 on April 10, 1849. Sadly, Hunt sold his patent for \$400 to pay off a debt.

Hunt's later inventions include a forerunner of the Winchester repeating rifle, a successful flax spinner, a knife sharpener, a streetcar bell, a stove that burned hard coal, artificial stone, road-sweeping machinery, velocipedes, ice ploughs, and mail sorting machinery.

Rosanne Welch

See also Repeating Rifle; Zipper

Further Reading

Petroski, Henry. 1994. *The Evolution of Useful Things: How Everyday Artifacts—From Forks and Pins to Paper Clips and Zippers—Came to Be as They Are*. New York: Vintage.

Sewing Machine, Automated

Like most significant events in business, an invention, or series of inventions, acts only as the seed for full commercialization. The market decides the usefulness of an invention, and the workplace determines the speed of implementation. The advent of the automated sewing machine is the perfect example of the process of commercialization of an invention and the evolution of a manufacturing process. The more classless society of America in the 19th century brought on a curious distinction from that of Europe. The lower- and middle-income groups had a propensity to dress well, approaching the dress of the wealthy. Tailors and seamstresses came together to "manufacture" clothing in factories such as the Quincy Hall Clothing Manufactory in Boston and Opdyke Manufacturing in New Orleans. Still, prior to 1850, just as Alexander Hamilton had reported in his 1794 *Report on Manufacturing*, about 70 to 80 percent of American clothing was handmade. There was, however, a huge potential market if prices could come down. The automated sewing

machine would lead to a revolution in ready-made clothing.

Tailors were considered skilled craftsmen and formed guilds and unions. They were generally immigrants and were very sensitive to the automation of their crafts; the power loom had created major unemployment in the crafts in the early 1800s in Europe. In England, a group known as the Luddites had burned and destroyed power looms from 1811 to 1813. Similarly, in 1841, French tailors had destroyed a factory of 80 semiautomated sewing machines, fearing job loss. In America, there was less pressure, but tailors still resisted automation. The market potential, however, could not hold back creativity in the United States. The French sewing machine and early American machines of the 1830s showed little promise, but creativity continued, driven by the market. One of the first machines was that of Walter Hunt, but he discontinued its development, fearing that low-wage seamstresses would lose their jobs. Not surprisingly, several other inventors appeared on the scene simultaneously in the 1840s.

One of the first successful patents for automated sewing machines was that of Elias Howe in 1846. The Howe machine had many limitations, such as being hand cranked, had a limited seam length, and had to be readjusted often, but it did serve as inspiration for further development by others, including Isaac Singer. He improved on the Howe machine; for one thing, it was driven by a foot pedal. He faced an army of lawyers defending the Howe patent, but Singer proved the better salesman, successfully selling his \$2,000 machine to factories. Ultimately, Singer lost a patent infringement case to Howe; Singer had impacted the market and chose to pay royalties to Howe. A number of inventors entered the battle, which became known as the “Sewing Machine War” and would augur future legal battles over inventions in America. At least 10 inventors had received patents on machine improvements, particularly regarding thread-feeding systems and types of stitch.

While the sewing machine did reduce clothing costs and allowed for more customization, manufacturing companies became bogged down with patent infringement cases. Various inventors had keys to full automation; for example, Benjamin Wilson’s 1849 patent for automated thread feeding was as critical as

Howe’s and Singer’s features. The manufacturers brokered an 1856 deal between the inventors, which was known as the “Sewing Machine Combination.” The various patent owners pooled all their features for the sewing machine into a single fee, and they also had the franchising rights for manufacturers. Howe, whose machine had never been a commercial success, became the highest paid of the inventors, receiving \$5 per machine sold. The others shared a royalty of another \$10 per machine. The combination agreement remained in effect until 1877. Years later, General Electric and Westinghouse Electric would use this patent-pooling business model to end the “war of the currents.” Today, such arrangements would not meet the test of our antitrust laws.

The Singer sewing machine not only revolutionized the clothing industry but also automated the shoe industry by 1860. The Civil War and President Abraham Lincoln’s domestic manufacturing and tariff policies created the ready-made clothing market. The government submitted a type of standard sizing for military uniform manufacturers, who used this statistical normal distribution of human sizes to develop the science of sizing—that is, that certain measurements occurred with predictable repeatability. The combination of automation and market made clothing America’s major business in 1870. The clothing market doubled from 1860 to 1870 and reached a billion dollars by 1890. Similarly, the shoe market grew. The sole- sewing machine in 1858 revolutionized shoe manufacture. Ready-made, standardized shoes took over the market by 1890. Now, a customer knowing his or her size could shop at the newly emerging department stores of the 1890s. Sewing machine sales from 1860 became an international market, which the United States dominated.

Singer proved the best marketer, and by 1865, he controlled 70 percent of the market. In 1877, Singer went on to add the continuous-stitch feature and formed the Singer Sewing Machine Company. Singer electrified his machine first in 1889 to further increase productivity. The time to make a simple dress dropped from 10 hours for handmade to under 1 hour with machines in 1890. The skill level dropped from that of a craftsman tailor to that of a simple laborer. Automated sewing led to labor specialization and subassembly operations. The automation further led to the

“sweating” system (task system) in which subcontractors opened small shops in the poor districts of New York and Chicago. These shops used cheap immigrant women workers. The manufacturers cut the cloth, marked the parts, and enclosed instructions for the subcontractors, allowing for a form of standardized mass production. Individual families even got into the bidding process, working out of their homes. The bidding among subcontractors drove costs and prices down. The system of subassembly and bidding is an early example of supply chain management. Abuses would lead to a general strike in 1910 of 40,000-plus immigrant garment workers. The strike led to the formation of the United Garment Workers and the Amalgamated Clothing Workers of America.

Quentin R. Skrabec

See also *Vol. 1, Sec. 2: Patent and Copyright Statutes*

Further Reading

- Boorstin, Daniel. 1974. *The Americans: The Democratic Experience*. New York: Vintage Books.
- Montgomery, David. 1987. *The Fall of the House of Labor*. Cambridge: Cambridge University Press.
- Schlereth, Thomas. 1991. *Victorian America: Transformations in Everyday Life*. New York: Harper Perennial.

Sewing Pattern

The tissue sewing pattern was developed by Ellen Curtis Demorest in the 1850s. Her inspiration came one day as she watched someone cut out a pattern on rough wrapping paper. She reasoned that producing a pattern on thinner paper could be easily done and the resulting patterns distributed at low cost. She and her sister, Kate, had been working on numerous ways to accurately cut out dress patterns. After working on various charts for seven years, they felt that they had accomplished this task.

Ellen Demorest was born in 1825. Raised in Ballston Spa, near Saratoga, New York, she had a simple but comfortable upbringing. Her father owned a hat factory where the bestselling hats cost \$20 and up. With the opening of the Erie Canal and the railroad extension into Saratoga, the area became prosperous

as new kinds of businesses appeared. During the 1840s, as the town became a popular resort area that the wealthy visited during the summer. From watching the wives and daughters of rich men, she developed a keen interest in ladies' fashion.

After graduating from Schuylerville Academy, Demorest decided to become a milliner. Millinery—designing, producing, and selling ladies hats—was considered an acceptable vocation for respectable women. Her father helped his daughter by giving her money to start a small business. By the end of the first year, Demorest relocated to Troy, New York, known as the center for millinery, where she soon became a superintendent of an established business. She met her husband, William Jennings Demorest, in Troy.

Together they worked on improving on the logistics of tissue patterns to make them more accessible to the population. The main goal was to ensure that dress patterns reflected ladies various shapes and sizes. The Demorests began by displaying a small collection of these tissue paper patterns to local women. Mr. Demorest sought to market the patterns broadly and quickly. In 1860, he published the first issue of *Mme. Demorest's Mirror of Fashions*, a 10-cent quarterly publication designed in blue with gold decorations on the cover. The paper patterns were also heavily advertised with a sample and became so popular that the Mme. Demorest's name became linked with her invention.

The Demorests' pattern business grew rapidly. All over the United States, women clamored for the dress patterns. By using the samples in the magazine, they could learn how to cut and sew the dresses. Pattern prices varied according to the article of clothing. Patterns for mantillas, basques, and bodices were less expensive than patterns for high-fashion dresses. The patterns were printed on tinted paper and were sold at retail stores, by mail order and at dressmakers' shops.

The Demorests' business continued to thrive for another two decades until the 1880s. For some unknown reason, they never patented the tissue paper pattern. Ebenezer Butterick saw this as an opportunity. Butterick created paper sewing patterns for children between the ages of three to five and patented them. The customized patterns for children proved to be a success. Butterick expanded his business in 1863 by selling men's and boys' patterns according to size.

Three years later, he added patterns for women's clothing—these were sized using a system based on bust measurement. As his business expanded and thrived, he ventured into magazines and founded the *Semi-Annual Report of Gent's Fashions* in 1865. By the 1870s, he was also publishing the *Ladies' Report of New York Fashions* and *The Metropolitan*, a monthly offering that covered literature and fashion, including Butterick's sewing patterns. *The Metropolitan* would change its name to *The Delineator* in 1875 and continue publication until 1936.

Sewing patterns continue to sell well in the United States. Simplicity, McCall's, Vogue, and Butterick all have a considerable presence in most fabric stores.

Marilyn Chin

See also Rotary Hook (for Sewing Machines); Sewing Machine, Automated; *Vol. 1, Sec. 2: Cotton Sewing Thread*

Further Reading

- Burman, Barbara, ed. 1999. *The Culture of Sewing: Gender, Consumption and Home Dressmaking*. New York: Berg.
- Ross, Ishbel. 1963. *Crusades and Crinolines*. New York: Harper & Row.

Solar Compass

The solar compass is a device used by surveyors to determine the four cardinal directions (north, south, east, and west) using the position of the sun. It provides accurate survey results in areas where magnetic compasses malfunction.

There have been many variations of magnetic compasses since the Chinese used a lodestone (magnetite) in the first century. Compasses used in 19th-century America consisted of a magnetized needle on a pivot in a case. The needle rotated on the pivot, orienting with the earth's magnetic field to point north.

Magnetic compasses are very reliable close to the equator, but their accuracy decreases as latitude increases. Moving away from the equator and the accompanying fluctuations in the earth's magnetic field affect their ability to determine magnetic north. Large ore deposits also interfere with their accuracy.

U.S. Deputy Surveyor William Austin Burt (1792–1858) worked in the Midwest (Michigan, Wisconsin, and parts of Iowa) and found results in certain areas of these states were erratic so not always verifiable. These problem areas contained large mineral deposits such as iron ore that caused magnetic compass needles to spin nonstop. If a needle did stop, it gave incorrect results. Burt thought the iron deposits in these areas were large enough to interfere with the accuracy of compasses, so he invented a solar compass.

Made of brass, the solar compass is a combination of zinc and copper and therefore not magnetic. It consists of an upper and lower plate. The upper plate displays a needle box and three arcs. One arc is set to the latitude of the survey area, the second arc is set to the sun's declination (the sun's degree of angle in the sky based on time of the year), and the third arc is set to the hour of the day. The compass sights are on the lower plate, and it has a set of convex lenses. The apparatus is attached to a tripod for stability. Its results are accurate in areas with or without mineral deposits and at any latitude.

Burt patented the solar compass on February 25, 1836 (patent number 9428). Improvements were made over several years, and Burt received two additional patents—one in 1840 and another in 1851. Since Burt's solar compass was not affected by latitude, mineral deposits, or fluctuations of the earth's magnetic field, it was used for almost 150 years. The solar compass remained a valuable resource until the late 20th century, when global positioning system (GPS) technology was introduced.

Linda Briley-Webb

See also Equatorial Sextant; *Vol. 3, Sec. 1: Global Positioning System (GPS)*

Further Reading

- Burt, William Austin. 2008. *A Key to the Solar Compass, and Surveyor's Companion*. Miami, FL: HardPress.
- Johnson, Mark. 2003. *The Ultimate Desert Handbook: A Manual for Desert Hikers, Campers and Travelers*. Camden, ME: Ragged Mountain Press.
- Merrill, Ronald T., and Michael W. McElhinny. 1983. *The Earth's Magnetic Field*. London: Academic Press.

Spar Torpedo

The spar torpedo was first devised in 1810 by the inventor Robert Fulton, who designed, but never built, torpedo boats that would fire harpoons into enemy ships; the harpoons would then reel explosives in and a second rope would be pulled to start the clockwork detonator.

When the spar torpedo was resurrected during the Civil War, Fulton's elaborate mechanism was abandoned in favor of a simpler mechanism. The navy of the Confederate States of America was sorely outclassed by the U.S. Navy; to break the blockade of Southern ports, the Confederacy turned to a number of experimental weapons, including ironclads, submarines, and spar torpedoes.

The version used by the Confederacy was invented by E. C. Singer, who made his name by manufacturing naval mines. Singer was hired by the Confederate Engineering Department, along with his crew, to conduct spar torpedo attacks using the *H. L. Hunley*, a primitive submersible that Singer had also helped to develop. Singer's torpedo was carried on the end of a long boom in front of the *Hunley* and was detonated using a spring mechanism.

While the *Hunley* was still being constructed, another Confederate group used a spar torpedo on a small boat to badly damage the USS *New Ironsides* on October 5, 1863. The *Hunley* was the first submarine to sink a ship when it attacked the USS *Housatonic* on February 17, 1864. It had been long assumed that the spar torpedo was a suicide weapon and that the blast must have knocked some of her crew unconscious, but the *Hunley* was observed firing a flare to indicate a successful mission, and its wreck was discovered in 2000 not far from Charleston's harbor.

The U.S. Navy adopted the spar torpedo and used it to sink a Confederate ironclad in October 1864. Before long, slightly longer and safer spar torpedoes were in service with many navies. The Russian Navy used them extensively in wars against the Ottoman Empire, and a French punitive expedition in China used them to sink several gunboats in a single battle.

While spar torpedoes were not phased out until around 1900, they were used rarely; naval combat took place at increasing distances as gunnery improved.

Most of these torpedoes were mounted on small, fast boats in hopes of getting close and evading an enemy ship's heavy guns before attacking. The spar torpedo was nearly revived in 1945, when a desperate Japan trained a small unit of kamikaze divers to thrust explosive spears against ships at arm's length. Most of that unit died in training, and it was disbanded at the war's end without seeing action.

James L. Erwin

See also Torpedo; *Vol. 1, Sec. 2: Submarine*

Further Reading

Branfill-Cook, Roger. 2014. *Torpedo: The Complete History of the World's Most Revolutionary Naval Weapon*. Barnsley, UK: Seaforth.

Hacker, Barton C. 2016. *Astride Two Worlds: Technology and the American Civil War*. Washington, D.C.: Smithsonian Institution Press.

Steam Locomotive

A steam locomotive used the power of steam to move pistons mechanically connected to the main wheels of the vehicle rather than gas or solar energy and was prevalent in the United States in the 1800s. The steam was created on board by burning various combustible materials, which most frequently included coal and wood, in a boiler.

U.S. President Abraham Lincoln (1809–1865) understood both the challenges and vital importance of transportation in America. With such a huge landscape to cover from the Atlantic to the Pacific, Lincoln grasped the fact that canals and rivers simply could not be expected to keep pace with the country's growth, even with the powerful steamboats that plied the waterways. Nor could they provide the means for continued growth—there was just too much space to cover in the vast new country. As a former riverboat pilot, he knew that a more robust means of transporting goods and people would be crucial. He did not live to see the completion of the Transcontinental Railroad on May 10, 1869, but his vision for the United States—replacing regional loyalties with a sense of national destiny—came true.

The Transcontinental Railroad would not have come to fruition without the technological innovation of the steam locomotive—the “Iron Horse”—that powered it. The invention of the steam engine drove the Industrial Revolution in America, changing the way things were made and delivered to people all over the world. It changed the destiny of entire towns as well as the way of life for most people as the American economy diversified from being centered on agriculture to an industrial powerhouse. It brought people from around the globe to their new homes on the vast American continent. It created the American dynamo. Such was the power of the steam-driven Iron Horse.

The development of the steam locomotive dates back to 1763 with Scottish inventor James Watt’s improvements to the steam engine. The first full-scale steam locomotive was built in Britain by Richard Trevithick in 1804, though at the time, his steam locomotive was not well received.

Still, visionaries in the United States could see the potential. The Baltimore and Ohio was incorporated in 1827, with other rail companies soon to follow. In 1829, the Stourbridge Lion, brought from England, was the first steam locomotive in the United States and was tested along tracks built by the Delaware and Hudson Canal Company, which was diversifying for the future. The first steam locomotive to be built in America, Peter Cooper’s *Tom Thumb*, had its first run in 1830. It cruised at 18 miles per hour and carried 36 passengers. That same year, a steam locomotive known as *The Best Friend of Charleston* began regularly carrying passengers.

Along with hauling people, the steam locomotive transported goods at a much more rapid rate than was possible by horses or waterways. The railroad enabled people to know exactly when and where their goods would arrive. Despite what Hollywood westerns depict, trains also gave people and cargo a safer ride, as it was much more difficult to rob a train than a canal boat or horse-drawn transport. As more railroads were built, people and products could travel farther and faster than ever before.

Technological innovation kept advancing the steam locomotive, though it had begun as a relatively simple concept. The heart of the steam locomotive is a steam-powered engine. Fire is used to create heat, which boils water. This produces steam, which is

released into pipes. Pistons are connected to the locomotive’s wheels. As valves release the steam into chambers, which moves the pistons, the wheels move. By adding as many freight or passenger cars as the locomotive could pull, a remarkable new age was born.

Rail travel via steam locomotives caught on—well, like a runaway train. In 1830, the year the *Tom Thumb* had its first run, there were less than 25 miles of railroad tracks in the United States. Within 20 years, there were more than 9,000. There was a good reason for this: the federal government passed its first Land Grant Act in 1850, opening about 180 million acres for railroad construction. The idea was to encourage railroad growth and help offset the financial burden of building and developing rail lines.

The Land Grant Act was also designed to attract settlers to the vast, undeveloped parts of the country in the West. The Act granted 10 square miles of federal land for every mile of rail built. During the legislative life of the Act, which ran until 1871, once-unwanted land became valuable. Native Americans were squeezed out. Much of California and Texas was closed to homesteading as so much prime land had been granted to railroad companies. Yet, once the government perfected the technique of granting land to the railroads, Congress enabled a similar piece of legislation: the Morrill Land Grant Act in 1862. That Act deeded almost 20 million acres of land to the individual states; they could sell the land and use the proceeds to endow at least one college. This was the genesis of more than 70 “land-grant colleges,” especially in the West, which helped build the nation along with the steam locomotive as the catalyst.

By the beginning of the Civil War in 1861, there were 30,000 miles of track. Over 21,000 of them were in the North. Throughout the war, railroads allowed the quick transport of large numbers of soldiers and heavy artillery over long distances. After the Battle of Chickamauga in 1863, Abraham Lincoln was able to send 20,000 badly needed replacement Union troops over a thousand miles from Washington, D.C., to Georgia. It was called the longest and fastest troop movement of the 19th century. The steam locomotive was a powerful factor in the North’s ultimate victory.

Even in wartime, a steam-powered transcontinental rail line was an important goal of Lincoln’s.

Through the land grants and low-interest government loans, entrepreneurs were encouraged to take on the challenge of laying rail from coast to coast. In 1862, these included California's "Big Four": Charles Crocker, Collis Huntington, Mark Hopkins, and Leland Stanford. However, the backbreaking work of doing so was done by immigrant men and women, mostly Chinese and Irish.

Ironically, Lincoln continued fostering steam-powered rail travel even after his death. Chicago's George Pullman had the idea of a comfortable railroad "sleeping car" after a particularly uncomfortable train ride he had taken in upstate New York. By 1863, he had produced his first two models, but they were too expensive for rail companies. After Lincoln's assassination in 1865, Pullman offered one of his railcars as part of the funeral cortege that traveled through several states, bringing Lincoln's body home to Illinois. Those people who did not line the tracks to see the steam-powered train could at least read about Pullman's railcar on the front pages. Publicity poured in about Pullman loaning one of his sleeper cars to the grief-stricken Mary Lincoln. The connection continued with Pullman's death in 1897 when Robert Todd Lincoln, the slain president's eldest son, became head of the Pullman Company.

Powered by the steam locomotive, the number of miles of railroad track climbed steadily until hitting its peak in 1916, when there were more than 250,000 miles of track—enough to reach from Earth to the moon. The impact of the technological innovation of the steam locomotive cannot be overstated. It enabled all forms of long-distance travel, from settling the West to carrying raw materials and finished goods to waging war. It united the far-flung parts of the country, boosted economic development, and was the catalyst for America's rise to the pinnacle of a world power.

Technology and innovation do not exist in a vacuum. Their value is often determined in unexpected ways, often transforming society. This was especially true of the steam locomotive. In the 19th century, railroads determined the fate of American towns both large and small. Those on the rail line flourished; others often withered. Especially in the vast expanses of the American West, towns on the steam-driven rail lines were connected to the rest of the world.

New terminology was coined during the heyday of the steam locomotive, including such literal terms as

"cowcatcher" and "bells and whistles." Since steam-driven locomotives needed water to create the steam, they had to stop frequently for replenishment. Some communities were too small to have refilling facilities, so rail crews had to stop next to streams and use buckets to fill the tender with water. Since they had the annoying task of "jerking" the water, communities too small even to have a water tank were derisively called "jerkwater" towns.

The steam-powered locomotive created American jobs. In the first place, tracks had to be built on which trains could travel. As time passed, greater demand for expanded rail service created the need for more track in more areas. Both locomotives and railcars had to be made and supplied all over the country. Then, as more people had access to goods, increased sales and greater demand drove factories around the nation to hire more people.

The steam locomotive even stimulated growth in one specific professional field: architecture. Rail depots had to be designed and built, with many having their genesis as "union stations," where tracks and facilities were shared by several rail companies, allowing passengers to connect conveniently between them. A few included Union Station in Columbus, Ohio, which first opened in 1850. The Indianapolis Union Station opened in 1853. Chicago and Denver each had union stations dating to 1881. Many were designed to have long-term architectural value instead of being simply boxes with tracks running through them.

Steam locomotives also had an impact in less obvious though far-reaching ways. For the first time, isolated communities were not subject to the threat of famine if there was a drought or disease that killed their crops, because more food could be brought in by rail. People were also safer, only having to travel to the nearest train depot to pick up goods and supplies rather than make long treks across hostile country to more urbanized areas to stock up. A whole new world was opened up for women who, prior to the advent of the steam locomotive, rarely traveled without escorts and had to slowly cross long distances by horse and wagon—easy targets for marauders.

By the 1920s, however, diesel and electric trains began to take the place of steam locomotives. Automobiles, trucks, airplanes, and the Great Depression of the 1930s all contributed to a general decline in

railroad ridership. By the 1950s, most passenger rail travel had dropped significantly. But in its heyday from the 1800s to the mid-20th century, the steam locomotive played a vital role in the survival, growth, and ultimate economic dominance of America.

Nancy Hendricks

See also *Best Friend* Steam Engine; Railroad T-Rail and Tie; *Vol. 1, Sec. 2*: Canals; Steamboat; *Vol. 2, Sec. 1*: Railroad Sleeping Car and Pullman Car; *Tom Thumb* Locomotive; Transcontinental Railroad

Further Reading

- Ambrose, Stephen E. 2011. *Nothing Like It in the World: The Men Who Built the Transcontinental Railroad, 1863–1869*. New York: Simon & Schuster.
- Drury, George H. 2015. *Guide to North American Steam Locomotives*. Waukesha, WI: Kalmbach.
- Wolmar, Christian. 2013. *The Great Railroad Revolution: The History of Trains in America*. New York: PublicAffairs.

Steam Shovel

A steam shovel digs up and transports rocks and soil. Patented in 1839 by William Otis, who was only 22 years old at the time, the Otis steam shovel is considered the earliest excavator. The steam shovel played a major role in the construction of railways as well as the Panama Canal during the 1800s and early 1900s.

The drawing of the steam shovel from Otis's 1839 patent is officially "missing," but a drawing has been found depicting a crane connected to a railroad car; the general consensus is that this was actually Otis's sketch. Otis started inventing his machine in 1835, when he was only 18 years old. Working with Carmichael and Fairbanks, he used a railroad segment between Norwich and Worcester, Massachusetts. After this initial machine was tested, Otis moved to Philadelphia to work alongside the operator of Garrett and Eastwick: the reputable Joseph Harrison. Together, they created a model for the steam shovel and even received a patent in 1836. However, their designs were soon destroyed in an unfortunate fire. Over the next three years, Otis worked to recreate and later improve what had been lost. In 1839, he received a patent for

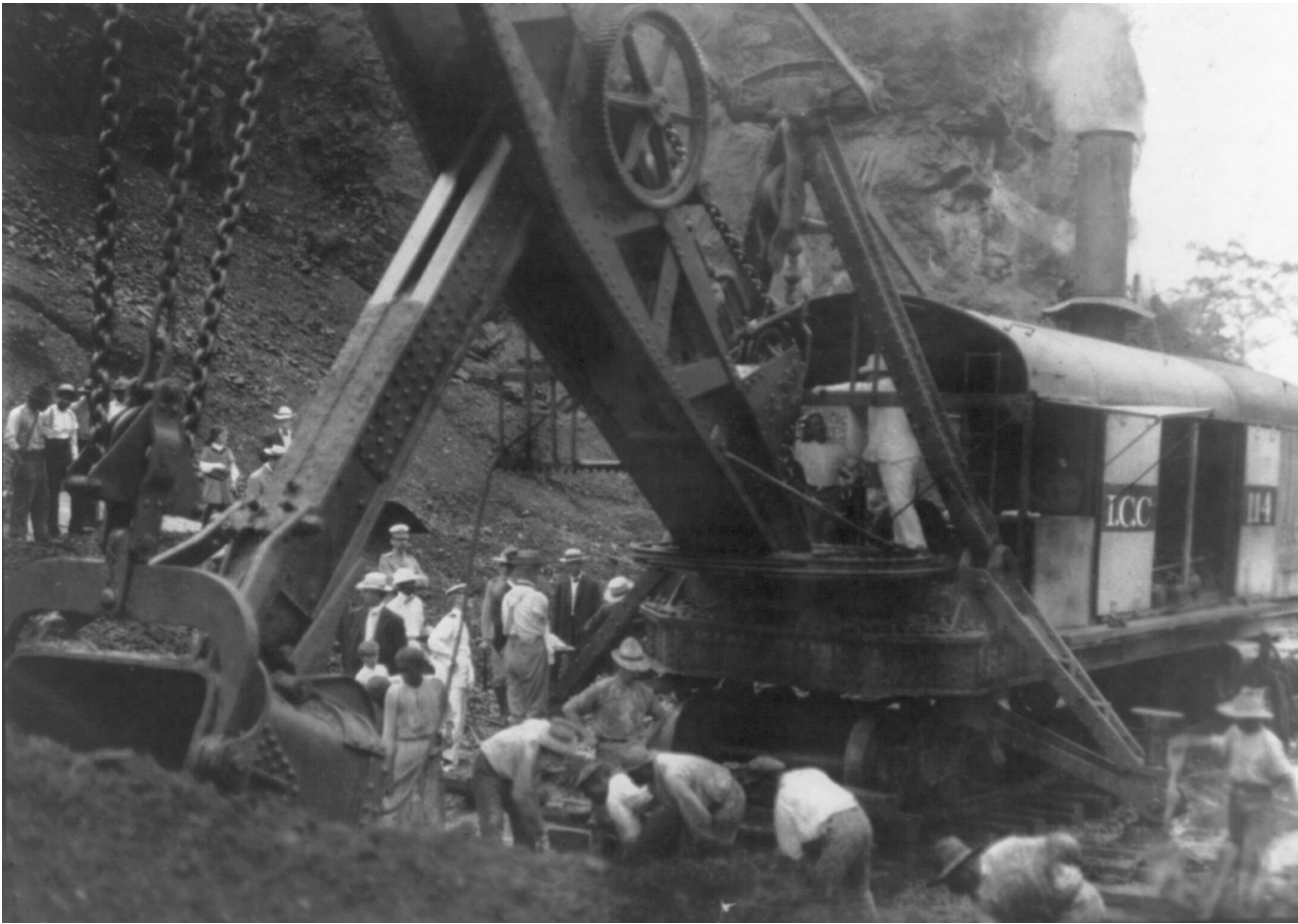
what he called a "Crane-Excavator for Excavating and Removing Earth," soon to be known as the "steam shovel." Less than a year after his patent was issued, William Otis passed away at the early age of 26.

The steam shovel had three main components—the bucket, the "dipper," and the "boom." The bucket was connected to the boom via the dipper and was used to dig and move earth. Coal was used to boil water and create steam, which powered the shovel. The shovel itself could rotate as well as move the boom and the dipper to perform the required operations. The dipper stick was repeatedly moved to fill the bucket with dirt and rocks. Once the bucket was full, the shovel could be rotated to fill up a nearby railroad car or other receptacle to remove earth from the area.

Steam shovel crews typically consisted of three people: an engineer, a fireman, and a ground man. Each person was completely necessary because there was a lot of hard work to be done not only to move earth but also simply to move the shovel into the right location and position. Earlier models used their own booms to maneuver themselves; they were not propelled by any other means.

The steam shovel's popularity grew as a result of the railroad industry. Railroad construction required large amounts of material to be moved for miles and miles. Steam shovels were put to work all over the country to help with the cause. Some of the fastest-growing cities even used the steam shovel to dig skyscraper foundations. The shovels were especially useful in digging mines—Minnesota iron mines and the Klondike mines, among many others—but the open-pit mines in Bingham Canyon, Utah, were some of the most memorable. Steam shovels literally removed hills over a period of time. These mines would serve as examples to other countries, including Australia and China. It was not long before the steam shovel was in use all over the world. The most notable example of the great technological prowess of the steam shovel was the decade-long construction of the Panama Canal, built by the United States from 1904 to 1914. Over 100 steam shovels were used on the project, most of them manufactured by Bucyrus or Marion Steam Shovel Company.

Although William Otis's steam shovel served a great purpose in American history, it is no longer used as a



President Theodore “Teddy” Roosevelt near the controls of a steam shovel at the construction site of the Panama Canal in 1908. Steam-powered machinery like this shovel allowed for larger, more complicated building projects. (Library of Congress)

method of excavation. During the 1930s, diesel-powered shovels took over the industry due to their simple design and inexpensive price. Other multiton shovels have been manufactured for specific projects after the fall of the steam shovel era; they are known as power shovels because they use electricity instead of steam. Most steam shovels have been dismantled, but a few remain in museums or private collections in remembrance of such a monumental technological advancement.

Brenna Biggs

See also *Vol. 1, Sec. 2: Steam Engine*

Further Reading

Marsh, Robert, Jr. 1920. *Steam Shovel Mining*. New York: McGraw-Hill.

Stetson. See Cowboy Hat (Stetson)

Stevens, Robert Livingston (1787–1856)

Robert Livingston Stevens was a member of a family of engineers whose inventions improved transportation on land and water. Stevens, born on October 18, 1787, in Hoboken, New Jersey, was one of the 11 children of John Stevens (1749–1838) and Rachel Cox Stevens. John, known as “Colonel” from his service as treasurer of New Jersey during the Revolutionary War, had come from a wealthy family, and after graduating from King’s College (now Columbia University) and then studying law, had become interested in mechanical engineering. Having to commute slowly by boat

between houses in lower Manhattan and Hoboken, John was intrigued by the earlier experiments of John Fitch and James Rumsey with steamboats. John persuaded Congress to pass the first patent law in 1790, and a year later, he took out three patents related to steamboats and a multitubular steam boiler. Working with both his brother-in-law Robert Livingston (who was chancellor of New York and had obtained Fitch's monopoly of the right to navigate steamboats in that state) and Nicholas Roosevelt, John launched his first steamboat, the *Polacca*, in 1798, but it was not a successful design. The three men, however, agreed to be partners in steamboats for 20 years.

Robert worked closely with his father, including the design and construction of the *Little Juliana*, the first twin-screw-propelled steamboat, which Robert and his older brother John Cox Stevens successfully operated across the Hudson River in 1804. The boilers and engines of that era, however, could not produce the high pressure needed for screw propulsion, so Robert and his father reverted to the paddle wheel on the *Phoenix* (1808), which Robert designed with concave waterlines. The adoption of the propeller for steam navigation would begin after both Francis Pettit Smith (1808–1874) and John Ericsson (1803–1889) received patents for screw propellers in 1836.

The *Phoenix* was the first successful steamship to be entirely American in origin, but its success was overshadowed by Robert Fulton's *Clermont* (1807), which used an English engine made by James Watt. Since Fulton was allied with Livingston, who still had the monopoly on Hudson River navigation, the Stevenses were forced to send the *Phoenix* to Philadelphia, with Robert on board for the first ocean voyage by a steamboat. Robert designed over 20 steamboats during his lifetime, and each improved upon the previous one. The *Juliana* became the world's first steam ferry (1811), operating between Manhattan and Hoboken, before threats from Fulton and Livingston forced the Stevenses to move the boat to Connecticut. Among Robert's inventions for steamboats and engines were guard beams supported by iron rods, the camboard cutoff, the use of anthracite coal in boilers, the gallows frame, skeleton walking beams, the hog frame, the balance valve, and spring pilings for ferry slips. Robert was also the first to build a pilothouse to protect the boat's operator.

Colonel John Stevens and his sons were also early proponents of railroad transportation. John argued for construction of a steam railroad instead of building the Erie Canal. He and Robert built the first locomotive in the United States (1826) and ran it on a circular track on the family's Hoboken estate to demonstrate the potential of railroads. In 1830, Robert and younger brother Edwin formed the Camden & Amboy Railroad to run between New Jersey and Pennsylvania. While on a trip to England to order rails and acquire the *John Bull* locomotive, Robert designed a new rail system (it became known as the "T rail") that became the standard section on all American railroads. He also invented the cowcatcher to sweep track obstacles aside in front of locomotives. Other railroad innovations by Robert were the hook-headed spike and the "iron tongue" (fish plate), the use of wooden ties with crushed stone ballast for the rail bed, and the double-slide cutoff for locomotives and large engines.

During the War of 1812, John designed a saucer-shaped ironclad ship for harbor defense that would swivel by the use of screw propellers, but it was never built. Robert developed an elongated shell that could be fired from an ordinary cannon and would explode after penetrating its target, which the federal government eagerly bought. In 1841, Robert and Edwin expanded their father's earlier ironclad proposal and sought government funding to build a huge ironclad steam vessel that would be impenetrable "to shot or shell" with all machinery below the waterline and would use screw propellers to pivot quickly in place.

Congress authorized \$250,000 for them to begin building the 410-foot long "Stevens Battery," but construction went on for decades, and the ship was never finished—as more powerful guns and shells were developed, the ironclad's design was continually changed. After Robert's death (April 20, 1856), Edwin offered to complete the Stevens Battery, but the government declined him. During the Civil War, Edwin built a smaller ironclad vessel, the *Naugatuck*, to demonstrate that the initial plan for the Stevens Battery was indeed practicable. Edwin died in 1868 and left the unfinished Stevens Battery to the state of New Jersey along with \$1 million to complete it—but the money ran out, work was suspended, and the unfinished ironclad was eventually sold as scrap in 1880.

Edwin also bequeathed land and funds for the founding of the Stevens Institute of Technology in Hoboken, which developed a school of mechanical engineering.

John A. Drobnicki

See also *Vol. 1, Sec. 2*: Erie Canal; Fulton, Robert; Multitubular Boiler; Steam Engine; Steamboat

Further Reading

Allen, Oliver E. 1987. "The First Family of Inventors." *American Heritage's Invention & Technology Magazine* 3, no. 2: 50–58.

Bianculli, Anthony J. 2008. *Iron Rails in the Garden State: Tales of New Jersey Railroad*. Bloomington: Indiana University Press.

Furman, Franklin De Ronde, ed. 1905. *Morton Memorial: A History of the Stevens Institute of Technology*. Hoboken, NJ: Stevens Institute of Technology.

Stevens, Francis B. 1893. "The First Steam Screw Propeller Boats to Navigate the Waters of Any Country." *Stevens Indicator* 10, no. 2: 101–30.

Turnbull, Archibald Douglas. 1928. *John Stevens: An American Record*. New York: The Century Co.

Strauss, Levi (1829–1902)

Levi Strauss is known today for coming to the California gold rush, failing as a "forty-niner" but succeeding as a shopkeeper, as most of the money was to be made in selling things to miners rather than in being one. In the process, he is said to have invented denim jeans, which are named for him as Levi's. While the first facts are true, the second is only half true. Denim jeans were already worn by many miners, ranchers, and farmers, appreciated for the durability of their fabric over that of linen or cotton clothing. But it was not until Jacob Davis, a Nevada tailor, developed a process for securing the seams and riveting them at the pockets and the base of the button fly that they became ubiquitous.

Strauss was born to a Jewish family in Bavaria in 1829 and emigrated to New York in 1847 at the age of 18. His older brothers had established a dry goods business, and he worked for them, traveling to Kentucky for three years with product to sell. Strauss became an

American citizen in January of 1853 and then moved to San Francisco. With two older brothers and a sister, they established a dry goods store as the city boomed with citizens making money off of the miners.

They opened one store on Sacramento Street in downtown San Francisco and by 1866 opened larger headquarters on Battery Street. Strauss was a well-known community leader when Davis approached him with his new denim sewing techniques in 1872. Davis ran a tailor shop in town, making everything from tents to horse blankets and wagon covers using fabric purchased from Strauss's stores.

Davis could not afford to patent his riveting process, so he asked Strauss if he would pay the fee and share the patent. Being a good judge of ideas and talent, Strauss agreed. Then he brought Davis to San Francisco to oversee the pant manufacturing for his business, Levi Strauss and Company, incorporated by Strauss and his sister's four sons, who ran the day-to-day operations. The company became the first in the United States to manufacture what were generically called "blue jeans" but quickly came to be called Levi's. The two men maintained their working relationship for the rest of their lives, with Strauss dying in 1902 and Davis in 1908.

Jeans, or Levi's, remained a working man's pant for nearly 50 years after their deaths, when teenagers from subsequent eras began to adopt them as daily wear. In the 1950s, they represented poorer subcultures known as "greasers"; in the 1960s, hippies embraced the style, and in the 1970s, punk rockers preferred the predistressed and washed-out looks.

Rosanne Welch

See also Cowboy Hat (Stetson); Hoop Skirt

Further Reading

Sullivan, J. 2006. *Jeans: A Cultural History of an American Icon*. New York: Gotham Books.

Telegraph

The telegraph, patented by Samuel F. B. Morse in 1840, had an incalculable impact on the developing United States. While its dominance was comparatively

short-lived, the invention and development of the telegraph nevertheless had a tremendous impact on the growth and development of the country in the mid-19th century.

In some ways, Morse was an unlikely father of such an invention. His creativity was unquestionable, but after graduating from Yale College in 1810, he pursued a career in art and became a well-regarded painter. But that artistic bent was complemented by a scientific mind, one that had been transfixed by a series of lectures on electricity that he had attended at Yale. In 1832, that longtime, continuing interest in electricity led him to pursue the idea of an electric telegraph after overhearing a conversation about the newly discovered electromagnet.

Morse believed his idea was an original one, but in fact, the concept had been proposed as early as 1800. Undaunted by the possibility of competitors, though, this artist pursued the project with an impressive determination, constructing his first working model around 1835. Although he continued to pursue his art while also teaching at the University of the City of New York (later New York University), his primary focus was on developing his telegraph. Drawing upon his university connections, he was aided by a colleague, chemist Leonard Gale, and his friend Alfred Vail in the effort to develop the new machine. In 1838, Morse and Vail originated the system of dots and dashes that would become the Morse code, but even with this language in hand, they were unable to convince Congress to undertake the construction of the telegraph line necessary to make the system operational. Rebuffed at home, they turned to Europe for support to construct a telegraph line there, but that effort, too, came to naught.

Discouraged, Gale and Vail abandoned the project, but Morse continued his efforts and in 1840 was awarded the first U.S. patent for it. Finally, in 1843, Congress gave Morse sufficient financial support to construct the nation's first telegraph line—one that went from Baltimore to the nation's capital. Completed in 1844, on May 24, Morse sent the first message—"What hath God wrought"—and ignited a communications revolution. Indeed, limited only by the time involved for the construction of the network, the telegraph transformed communication first along the East Coast and eventually across the nation, and in Europe as well.

Allowing cross-country communication in a manner never before imagined, the telegraph served to connect the nation, breaking down regional barriers and playing a crucial role in the development of an increasingly national identity and character. In facilitating faster and broader communication, the innovation helped erase many of the regional distinctions that had characterized the nation's earliest years. Indeed, the telegraph was without question the single most important means of long-distance communication in the first century of the American republic. Whether it was used to transmit national news or family developments, the telegraph served to shrink the nation at a time when western exploration, the Mexican War, and the California Gold Rush encouraged expansion. Indeed, the role of the telegraph in communication during the Civil War, as well as its role in the actual development of the West, specifically the way it connected the far-flung western areas both with each other and with the more populous eastern cities, represents some of its greatest historical impact.

It also had a major impact on the national economy. In fact, the telegraph grew almost hand in hand with the other commercially critical development of the period—the railroad—and through their parallel development, the 3,000-mile chasm between the East and West Coasts was bridged in a way that fostered the nation's economic, social, and political development to an unimagined degree. That almost partner-like relationship helped set the stage for the nation's emergence as a world economic power.

While it would take longer to have an impact in the West, where the prospect of stringing the lines necessary was a daunting task given the sparse population and the wide spread of settlements, it is arguable that some of its greatest impact was there—at least in the way it both fostered Western growth while preventing newly settled areas from becoming isolated outliers. The surge of settlers who invaded California beginning in 1849 following the Gold Rush created a sense of urgency and quickened the efforts to string the wires needed to connect the farthest western parts of the nation with their eastern counterparts.

Not surprisingly, the telegraph's development in many ways mirrored the country's, with population and technology initially jumping over the plains states to

California and then later moving eastward to meet up with the ever-increasing migration from the east. Indeed, a disparate collection of telegraph lines dotted the West Coast in the decade following the Gold Rush. In short order, California was witness to the creation of a number of short-range lines set up in such a way that ultimately, San Francisco was connected with Sacramento and Stockton and San Jose. Soon afterward, plans were underway to develop a network heading east from California to Nevada. Meanwhile, the late 1850s saw Missouri undertake similar local efforts, and these were eventually coordinated with the existing eastern networks so that cross-country communication from New York and Washington to the outer reaches of the settled west in St. Louis on the Mississippi River was possible. However, with these advances, the question of a transcontinental connection loomed large.

Another outgrowth of the telegraph was the emergence of the government as a vehicle for actively fostering economic progress. Reflective of this phenomenon was the passage in June 1860 of the Pacific Telegraph Act, legislation that authorized the expenditure of almost half a million dollars over 10 years to construct a telegraph line from the western border of Missouri to San Francisco. This effort was motivated at least in part by the growing recognition that the communication afforded by the development of a true transcontinental telegraph network would allow for the development of truly national businesses, as well as for quick commercial transactions between the eastern bankers and western developers whose efforts they were funding.

In addition, the Civil War heightened the existing sense of urgency concerning the development of a widespread telegraph network. The Lincoln administration recognized that in a national war, the telegraph offered a distinctive and never-before-available means of communication, one that could be critically important for coordinating and directing troop movements as well as sharing wartime news. These factors became particularly important as the war dragged on far beyond initial expectations.

The process of growth went forward, and to the astonishment of most observers, results were achieved with almost lightning speed. Setting their first poles in the ground on July 4, 1861, the Western Union Telegraph Company, the major corporate outgrowth and benefactor of the telegraph boom, began the process of

stringing the wires to connect St. Louis with the network that already linked Nevada to San Francisco and other California cities. The efforts to string wires across hundreds of miles of often barren, unoccupied, and unsettled frontier was a truly monumental task, but upon completion, the nation had a wholly functional system (though admittedly rudimentary), one that allowed for the first transcontinental telegraph wire to be sent by California Chief Justice Stephen Field to President Abraham Lincoln on October 24, 1861. While the creation of the network was itself an impressive undertaking, its impact was no less monumental, for in extending the reach of the telegraph, the isolation of the West was markedly reduced, and the enhanced communication—and, in turn, the greater commerce—was no less so in its impact on American society.

While the creation of the transcontinental telegraph network was unparalleled, it was in fact, only a beginning, with work continuing in a determined effort to increase the reach of telegraphic communication. While the same challenges remained, additional poles and wires were installed across new expanses of isolated prairie. It was an arduous task, but progress was made, and as the Transcontinental Railroad developed in the aftermath of the Civil War, the telegraph also grew, in some cases literally, alongside it, all the while expanding its reach throughout the far-flung United States.

For all its early unprecedented and pathbreaking influence, the telegraph's era was comparatively short-lived. In 1876, less than a decade after the Golden Spike was driven, signaling the completion of the Transcontinental Railroad, there came the invention of the telephone, and in comparatively short order, a national telephone network, often using the same poles and wires that had fueled the telegraph, spanned the nation. But while its period of dominance may have been short, the legacy of the telegraph and its multifaceted impact on the United States cannot be overstated.

William H. Pruden III

See also Military Technology (Civil War); Vol. 2, Sec. 3: Telephone

Further Reading

Standage, Tom. 1998. *The Victorian Internet: The Remarkable Story of the Telegraph and the Nineteenth Century's On-line Pioneers*. New York: Walker & Walker.

Primary Document: Act Authorizing Construction of a Transcontinental Telegraph (1855)

In 1855, Congress authorized the construction of a transcontinental telegraph using public lands and private builders. The national telegraph system fundamentally changed communication in America, making it possible to communicate over long distances in a short time.

CHAP. CXII.—An Act authorizing the Construction of Line of Telegraph from the Mississippi or Missouri Rivers to the Pacific Ocean. Right of way Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That Hiram O. Alden . . . James Eddy, their associates and assigns, are hereby authorized and empowered to construct, at their own expense, a line of telegraph, from such point on the Mississippi or Missouri River as they may hereafter select, through the public lands belonging to the United States, over which lands the right of way two hundred feet in width, for that purpose, is hereby granted, to San Francisco, in California, in as direct a line as practicable.

SEC. 2. And be it further enacted, That all voluntary or intentional injuries to said line of telegraph, or to any property thereto belonging, Penalties for injuries to such telegraph, within the territories of the United States, shall be deemed, and are here-by declared to be wilful and malicious trespasses, and shall be punished as such; and all laws of the United States now in force in any territory thereof, or which may hereafter be enacted for the better security and protection of property, and applicable to such offences, shall be, and they are hereby, extended, for the protection of said line of telegraph, into and over all the territory belonging to, and under the jurisdiction of the United States, through which the same may be constructed; and all legal process and proceedings for the detection and punishment of the aforesaid offences shall be within the jurisdiction of the courts, and shall be issued and executed by the proper law officers in the States or organized territories. APPROVED, February 17, 1855

Source: *U.S. Statutes at Large*, 33rd Congress, 2nd Session, 110–12. Library of Congress.

Ten-Hour Movement

The Ten-Hour Movement was a labor reform movement that began in the 1840s, largely by female textile workers in Lowell, Massachusetts, to fight for a shorter workday. In the early 1840s, mill workers typically worked 11 to 13 hours per day. As competition increased and the price of cloth decreased, owners of textile mills looked for ways to maximize profits.

Speed-ups (increasing the speed of machinery to make operatives work faster) and stretch-outs (increasing the number of machines that operatives were expected to tend) were common practices. The premium system was also instituted, in which corporations paid cash bonuses to the overseers whose factories made the largest amounts of product. These practices caused great demands on the mill workers, though they were inconsistent among the many mills within Lowell. The one practice that was consistent was the long workday.

In 1840, U.S. president Martin Van Buren issued an executive order making 10 hours the legal length of the working day, but only for federal workers and those on government contracts, not employees of private corporations. Labor reformers decided to petition for similar working hours at the state level. In 1843, a petition with 1,600 signatures from Lowell, Massachusetts's workers was submitted to the statehouse.

In late 1844, the Lowell Female Labor Reform Association (LFLRA), led by mill worker Sarah Bagley, organized to demand a shorter workday. This was a cause the workers could fight for together as a single unit across all of the different mill corporations regardless of practices or working conditions in the individual mills. At this time, women began to identify themselves as the female working class and were united under the LFLRA motto, "Try again!" The LFLRA argued that the shorter workday would let workers lead healthier and better lives. These

women's actions led them into the political world, where their concerns began to be heard.

The state legislature appointed an investigative committee in 1845 that visited several mills in Lowell and also had several mill workers, including LFLRA president Bagley, testify about their working experiences. At the end of its investigation, the committee reported that the legislature did not have the power to determine hours of work and that the length of the workday must be decided between the corporations and the workers in the textile mills. Because organizers and petition signers were mostly female and committee members believed in the common courtesy idea that men should and would look out for women in the workplace, the report stated, "Operatives should rely on the good will of their employers, rather than on legislative intervention." The committee felt that restricting the workday would affect competition among the mills and wages. Wages, it noted, should be set by the market for the goods as well as negotiated between laborers and owners.

In November 1845, only a few months after the special committee report denied the workers' petition to limit the workday, committee head William Schouler ran for reelection as Lowell's representative to the state legislature. Due to his report, workers in Lowell strongly opposed his election, and he lost. Following his defeat, members of the Lowell Female Labor Reform Association published the following statement in *The Voice of Industry* newspaper:

Resolved, That the members of this Association tender their grateful acknowledgements to the voters of Lowell for consigning William Schouler to the obscurity he so justly deserves,

for treating so unjustly and so ungentlemanly the defense made by the delegates of the Association, by the special committee of the Legislature, to whom was referred petitions for the reduction of the hours of labor, of which he was chairman.

Petitions continued, with women and men workers united in action. The Massachusetts Senate launched another investigation, but this also failed to recommend legislation to shorten the workday. There was a slight reprieve in the long workday in 1847, when the corporations agreed to allow more time for meals. In 1850, a group of Free Soilers, liberal Democrats, and disaffected Whigs pledged to support the 10-hour day and were successfully elected to office. Future Massachusetts governor Benjamin Butler, from Lowell, led this effort, and he and other elected officials tried numerous times to pass legislation. Finally in 1874, a law that applied to only women and child workers was passed to limit the workday to 10 hours. The early 1840s actions of the LFLRA were a significant step toward enacting this critical legislation.

Ellen M. Anstey

Further Reading

- Dublin, Thomas. 1979. *Women at Work*. New York: Columbia University Press.
- Lowell National Historical Park. <http://www.nps.gov/lowe>, accessed August 22, 2018.
- Tsongas Industrial History Center. 2013. *The Ten-Hour Movement Women and the Early Labor Movement*. Teacher's Guide and Student Curriculum Packet. <http://www.uml.edu/tsongas>, accessed August 22, 2018.

Primary Document: Excerpt from the Preamble and Constitution of the Lowell Female Labor Reform Association (1846)

The Lowell Female Labor Reform Association formed in 1845 to agitate for a 10-hour workday. Before the end of its first year, it had over 500 members. The following is an excerpt from the organization's preamble and constitution, in which the group argues

that its members cannot improve themselves if they do not have a reasonable workday.

Whereas we, the Operatives of Lowell, believing that in the present age of improvement nothing can

escape the searching glances of reform; and when men begin to inquire why the Laborer does not hold that place in the social, moral and intellectual world, which a bountiful Creator designed him to occupy, the reason is obvious. He is a slave to a false and debasing state of society. Our merciful Father in his infinite wisdom surely, has not bestowed all his blessings, both mental and moral on a favored few, on whom also he has showered all of pecuniary gifts. No! to us all has he given minds capable of eternal progression and improvement!

It now only remains for us to throw off the shackles which are binding us in ignorance and servitude and which prevent us from rising to that scale of being for which God designed us.

But how shall this be done? How shall the mass become educated? With the present system of labor it is impossible. There must be reasonable hours for manual labor, and a just portion of time allowed for the cultivation of the mental and moral faculties and no other way can the great work be accomplished.

We know no employment is respectable only as long as these employed are such, and no farther than they are intelligent and moral, can they merit the companionship and esteem of their fellow-beings. It is evident, that with the present system of labor, the minds of the mass must remain uncultivated, their morals unimproved, and our country be flooded with vice and misery!

Shall we, Operatives of America, the land where Democracy claims to be the principle by which we live and by which we are governed, see the evil daily increasing which separates more widely and more effectually the favored few and the unfortunate many, without one exertion to stay the progress?—God forbid! Let the daughters of New England kindle the spark of philanthropy on every heart till its brightness shall fill the whole earth! . . .

Source: *Voice of Industry*, February 27, 1846.

Toothpaste

The development of toothpaste represented a major advance in personal hygiene and health care. Beginning as a homemade product made from an unimaginable combination of ingredients, toothpaste has developed into both a multimillion-dollar business as well as an important contributor to better dental health.

There is evidence of a paste being used to clean teeth as long ago as ancient Egyptian times. That version, reportedly composed of powdery substances ranging from crushed bones to burnt eggshells and ashes, appears to be a forerunner of the early 19th-century powders that sometimes included crushed burnt toast and bark as a form of abrasive. Herbal mints were included in an early attempt to make the taste more palatable.

Most early 19th-century powders were literally homemade mixtures, concocted at home based on word-of-mouth recipes. Prior to the development of the paste that emerged in the 1850s, these powders usually included a form of soap for cleaning that was

mixed with a variety of abrasives, the most common of which was a form of chalk. These pre-Civil War toothpastes, more powders than pastes, were replaced in the early 1850s by a new, pastelike product. Sold in a glass jar, “*crème dentifrice*,” as it was called, quickly became popular, changing the nature of tooth care forever.

Commercially, everything changed in 1873 when the Colgate Company, one of the nation’s largest soap and perfume manufacturers, began to mass-produce an actual paste, offering it in the traditional jar. Two decades later, in 1892, Dr. Washington Sheffield first offered toothpaste in a tube, his design being very similar to the modern version. Colgate soon followed suit, offering its market-dominant product in a tube all but indistinguishable from Sheffield’s.

The next major advance in the development of toothpaste came in 1914 when, following studies indicating that it significantly reduced cavities, fluoride was added as a standard ingredient. Around this same time, toothpastes containing reduced abrasives were developed, an advancement aimed at limiting problems stemming from overzealous brushing. Meanwhile, the



In 1880, a London doctor saw a painter using paint from collapsible tubes and borrowed the idea for toothpaste. Before tubes, tooth-cleaning compounds were generally powdered and sold in jars or cans. Colgate & Company began mass-producing toothpaste in tubes in 1896. (History of Advertising Trust/Heritage Images/Getty Images)

post-World War II era witnessed a new focus on ingredients that could help with disease treatment and prevention as well as matters such as tooth sensitivity. Also, newly developed toothpastes often included whitening ingredients. Others offered greater cavity protection while also helping combat plague, gum disease, and bad breath.

The growth of the business side of toothpaste production led to greater external scrutiny, and in 1934, the American Dental Association (ADA) for the first time undertook to rate products, giving an “accepted” label to those that were safe and had a therapeutic effect. The Food and Drug Administration (FDA) soon followed suit, categorizing toothpastes that did not contain fluoride or made no therapeutic claims as cosmetics. The ADA, while acknowledging that it does

not study every product, now recommends one of the five brands to which it has given the “accepted” label: Crest, Colgate with MFP, Aim, Aquafresh, and Macleans with fluoride. These efforts to get people to limit themselves to five acceptable toothpaste options and avoid those that have not been shown to have therapeutic value are a clear reflection of the changed nature and purposes of toothpaste.

William H. Pruden III

See also Colgate, William

Further Reading

Blain, Rebecca. 2005. “Dental Hygiene, an Ancient Practice—The History of the Toothbrush.” *ezone-articles.com*, March 6. <http://ezonearticles.com>

/Dental-Hygiene,-an-Ancient-Practice---The-History-of-the-Toothbrush&id=18906, accessed August 22, 2018.

Blumenthal, Deborah. 1982. "Beauty; Taking a Pasting." *New York Times*, June 20. <http://www.nytimes.com/1982/06/20/magazine/beauty-taking-a-pasting.html?pagewanted=all>, accessed August 22, 2018.

Connelly, Thomas P. 2011. "The History of Toothpaste: From 5000 BC to the Present." *Huffington Post*, November 17. https://www.huffingtonpost.com/thomas-p-connelly-dds/mouth-health-the-history-_b_702332.html, accessed August 22, 2018.

"History of Toothbrushes and Toothpastes." *Colgate.com*. <https://www.colgate.com/en-us/oral-health/basics/brushing-and-flossing/history-of-tooth-brushes-and-toothpastes>, accessed August 22, 2018.

Ksander, Yael. 2006. "The Invention of Fluoride Toothpaste." *Moment of Indiana History*, July 10. <https://indianapublicmedia.org/momentofindiana-history/the-invention-of-flouride-toothpaste/>, accessed August 22, 2018.

Torpedo

Today, a torpedo is an underwater, self-propelled missile fired from either a ship or submarine. Torpedoes are designed to detonate on contact, thus destroying their targets. In the 19th century, the term applied to stationary naval mines. Both the Union and Confederate Navies used early explosive weapons during the Civil War. The spar torpedo, which had an explosive on the end of a long boom triggered either by a spring mechanism or a long pull cord, was used with limited success by submersibles during the war. It was adopted by several navies and used in combat several times over the next few decades.

Early attempts to create underwater explosives were largely unsuccessful. In 1626, Cornelius Drebbel, who was Dutch but worked for the English King James I, attempted to attach underwater explosives to an early submarine. Drebbel put his invention to the test at the Siege of Rochelle as part of the Anglo-French conflict, but the experiment failed to produce

any real explosions. In 1776, the *Turtle*, an American submarine engineered and built by David Bushnell, also attempted torpedo technology by a different means. Bushnell designed the *Turtle*, a one-man submersible vehicle, to affix explosives onto the underwater portion of British ships. This experiment also failed.

Steamboat innovator Robert Fulton also experimented with underwater explosives. In fact, he coined the term "torpedo" in 1800 when he demonstrated his submarine, the *Nautilus*, to English, French, and Dutch investors. Like Bushnell, Fulton hoped to use his submarine to attach explosives to ships. Finding no takers for his ideas, Fulton shifted his attention to developing an exploding missile that would work without a submarine to put it in place. He demonstrated his "infernal machine" in 1805, but the British government declined to purchase the technology, believing it unfair and immoral. Fulton tried again with the U.S. government two years later. During the War of 1812, the U.S. Navy did deploy a torpedo to destroy a British ship, again with no success. The British heard of the attempt on its navy and decried the torpedo as cruel.

The U.S. Navy began producing its own torpedoes in 1885, based on a design conceived by John Howell in 1870. Howell's torpedo used a flywheel to drive its propeller. This simple design was able to go farther and drive straighter than a Whitehead torpedo, redesigned in 1866 by Robert Whitehead from a design conceived by Giovanni Luppis of the Austro-Hungarian Navy. Howell's torpedo was loud and required a steam turbine to impart energy to the flywheel. It was abandoned in favor of the British model. Many other navies developed home-grown alternatives but continued to buy superior Whitehead torpedoes, especially after Whitehead introduced gyroscope-driven models in 1895.

By this time, torpedoes had been used in several battles; their debut in large-scale combat came with the Russo-Japanese War of 1904. Even decades after their introduction, torpedoes remained unreliable weapons—the U.S. Navy did not receive fully tested torpedoes until nearly two years after Pearl Harbor.

After decades of refinement during the submarine patrols of the Cold War, today's torpedoes are

generations beyond their ancestors. They can travel at remarkable speeds, guided either by internal sensors or the ship that launched them via control wires. The Soviet Union deployed torpedoes armed with nuclear warheads, although none were ever fired.

James L. Erwin

See also Spar Torpedo; *Vol. 1, Sec. 1*: Bushnell, David; *Turtle Submarine*; *Vol. 1, Sec. 2*: Fulton, Robert; *Submarine*

Further Reading

Branfill-Cook, Roger. 2014. *Torpedo: The Complete History of the World's Most Revolutionary Naval Weapon*. Barnsley, UK: Seaforth.

Gray, Edwyn. 2004. *Nineteenth-Century Torpedoes and Their Inventors*. Annapolis, MD: Naval Institute Press.

Transatlantic Cable

Transatlantic cables are used to transmit electrical signals under the Atlantic Ocean for telecommunications between continents. Up to 99 percent of all international data travels through undersea cables, making them the most important medium in telecommunications. Data transmitted through transatlantic cables can be over eight times faster than data transmitted via satellites. Undersea cable technology is also comparatively cheaper to implement than that of satellites. The data transmitted through transoceanic cables includes, but is not limited to, text messages, phone calls, and Internet usage. Just as the first transatlantic cables, modern transatlantic cables must address the issue of signal losses during transmission.

The first transatlantic cables had the purpose of implementing telegraphic communications, and they aimed to replace telegrams carried by ship between the United States and Europe. Communication between the two continents could take as long as 10 days before undersea cables became successfully operational. The first cable was laid down by Cyrus West Field and the Atlantic Telegraph Company, between the Irish island of Valentia and the Canadian town of Heart's Content. The cable was ready for use

in 1858, 119 years after the invention of the telegraph by William Cooke and Charles Wheatstone. This achievement also marked the year of the first successful transatlantic telegraphic transmission.

The first official telegraphic exchange between the two continents came on August 16 in the form of a congratulatory message from Queen Victoria of the United Kingdom to the president of the United States, James Buchanan. It read, "Europe and America are united by telegraphy. Glory to God in the highest; on earth, peace and good will toward men." After three weeks of cable operation, chief electrician Edward Orange Wildman Whitehouse attempted to increase the voltage to account for signal losses, leading to cable failure.

Sir James Anderson and his crew on the ship *Great Eastern* attempted to lay down the second transatlantic cable in 1865, starting in the Irish island of Valentia. After about 1,062 miles of cable were laid down under the ocean, the cable snapped at the stern of the ship, halting the mission. A second attempt was successfully made by the *Great Eastern* in the following year. On this journey, the crew also retrieved the lost end of the first cable and reconnected it to its original end. By the end of 1866, North America and Europe had two operating cables for telegraphic communications. Telegrams could be transmitted between North America and Europe at the average rate of 0.1 words per minute and at the cost of 10 dollars per page.

Formerly, undersea cables were made of copper, costing approximately \$1 million per circuit. In 1956, the technology began to be replaced by coaxial cables—ones with inner conductors surrounded by tubular insulating layers that in turn were surrounded by tubular conducting shields. The TAT-1 cable (Transatlantic No. 1) was the first coaxial cable of its generation, implementing the transatlantic telephonic system. Modern undersea cables have replaced coaxial and copper cores with fiber-optic technology. The first fiber-optic transatlantic cable, TAT-8, was laid down in 1988, costing less than \$10,000 per circuit.

Modern transcontinental transatlantic cables commonly lie on the path of the earth's orthodrome, as this constitutes the shortest distance between the cities of New York and London. Originally, cables that followed this path tended to terminate in Ireland on the

eastern side and in Canada on the western side, although modern transatlantic cables have a myriad of landing points. There are hundreds of transatlantic cables currently in operation, and they may be categorized as either domestic or international cables. Domestic transatlantic cables have their landing points in the coast of a single country, while international transatlantic cables connect two or more countries together. Transatlantic cables may be also privately owned by single or several businesses.

There exists growing concern regarding the environmental effect of undersea cables, ranging from the waste produced during the cable lifecycle to the overall impact of undersea cable operation and management on wildlife. Generally, cable routes avoid coral reefs lying on their paths. It is believed that recommendations that undersea cable locations be left undisturbed so as not to damage equipment can have a positive impact on the wildlife living around the cable's path. However, this does not mitigate the negative environmental consequences of the cable itself. Sharks are known to be affected by the presence of undersea cables when they gnaw on them, but the reason for this behavior is not yet clear.

Modern cables contain different layers of material around an optical fiber core, with the purpose of protecting the signal throughout its travel. The signal is also amplified at exact points to account for signal losses with the use of optical communication repeaters and relays. The typical layers of a modern transatlantic cable, from outermost to innermost, consist of: polyethylene, Mylar tape, stranded steel wires, an aluminum water barrier, polycarbonate, copper or aluminum tube, petroleum jelly, and optical fibers.

Advancements in fiber-optic technology, such as research on optical amplifiers, are currently being undertaken to further improve transatlantic cables by reducing latency and increasing signal quality. These efforts reinforce the tendency to maintain undersea cables as the most important medium in telecommunications.

Sara L. Darella

See also Printing Telegraph; Relay; Telegraph; *Vol. 2, Sec. 3*: Telephone; *Vol. 3, Sec. 1*: Satellites and Space Probes

Further Reading

- Cookson, Gillian. 2013. *The Cable: Wire to the New World*. Stroud: History Press.
- Gordon, John Steele. 2003. *A Thread Across the Ocean: The Heroic Story of the Transatlantic Cable*. New York: HarperCollins.
- Hearn, Chester G. 2004. *Circuits in the Sea: The Men, the Ships, and the Atlantic Cable*. Westport, CT: Praeger.

Transverse Shuttle

The transverse shuttle was a lockstitch sewing machine component that drove a bobbin horizontally to create a lockstitch. The design, which exposed the bobbin, closely resembled a boat—and was also known as a “boat” shuttle for this reason. The transverse shuttle became popular in the “New Family” sewing machine sold by the Singer Manufacturing Company in the mid-1800s.

Sewing machine pioneer Elias Howe invented the transverse shuttle. Howe trained as an apprentice in the textile and carding industries from a young age and later learned precise instrumentation as an apprentice in a mechanic's shop. Not only did Howe secure the first U.S. sewing machine patent in 1846 for his lockstitch sewing machine, he also patented the zipper in 1851.

German sewing machine companies continued to use Howe's transverse shuttle design until World War II, when many manufacturers switched to arms production to support the war effort. The bullet-shaped vibrating shuttle, which drove the bobbin in an arc shape, eventually replaced the transverse shuttle.

Brenna Biggs

See also Howe, Elias; Rotary Hook (for Sewing Machines); Sewing Machine, Automated

Further Reading

- Howe, Elias. 1846. Improvement in Sewing-Machines. U.S. Patent 4750, issued September 10, 1846.

Twine Knotter

The twine knotter began the agriculture industry's mechanical revolution. The knotter, which binds grain bundles with twine, was developed by John Appleby. Appleby was born in New York in 1840 and moved to Wisconsin as a young adult. At the age of 18, he created a basic knotter, but the farming community was uninterested.

Appleby left his home and inventions to fight in the American Civil War in 1862. Upon returning home in 1865, he continued development of the knotter. He created another knotter that used wire to bind wheat bundles, but small pieces of metal stuck in the grain and hurt the livestock when the feed was ingested.

In 1878, he developed a knotter using a twine binder. Twine was not harmful if cattle ingested it. With the support of the farming community, Appleby patented the idea. The twine knotter was licensed to the Deering Harvester Company and was later used on machines from Cyrus McCormick and Champion Machine. The patent was sold to Champion Machine in 1881. John Appleby continued to invent before he passed away in 1917.

Brenna Biggs

See also Polished Steel Plow

Further Reading

Jones, E. R. 1928. "A Bit of Twine Knotter History." *The Wisconsin Magazine of History* 12, no. 2 (December): 225–27.

Twist Drill

Born in New Hampshire, mechanic Steven A. Morse patented the twist drill in 1861. Although Morse created the drill to cut metal, it could also cut concrete, plastic, and wood. With a \$30,000 stockholder investment, he opened the Morse Twist Drill and Machine Company in 1864. Although Morse left the company four years later, he acquired several other businesses and continued to manufacture cutting tools.

Morse showcased his twist drill and other tools to the public for the first time in Philadelphia at the 1877

Centennial Exhibition. His businesses continued to flourish well into the 20th century. During World War II, Morse's companies grew nearly 500 percent as a result of increased output as part of the war effort.

Steven A. Morse's twist drill has left a legacy. His twist drill bits have become the most common type of drill bit produced today. The twist drill bit's popularity is attributed to its low manufacturing costs as well as its many uses. Since the invention of the twist drill bit, Morse's companies have produced over 25,000 types of cutting tools, with uses from construction to orthopedic surgery.

Brenna Biggs

See also Ratchet Wrench

Further Reading

Stephen Ambrose Morse US patent 38,119 Improvement in Drill-Bits. Twist Drill Bit, Granted: April 7, 1863.

United States Capitol Building, Construction of

The project to build the United States Capitol Building was begun by President George Washington (1732–1799). Construction of the building took many years as builders periodically expanded on the original design. In addition, fire damage during a war, a need for expansion, and dilapidation brought on by age necessitated several reconstructions, additions, and restorations. Since its inception, the grandeur of the Capitol Building had been the product of artists who had added their impressive works of art and innovative builders who had expanded the structure.

The first capitol of the United States was established in Philadelphia. However, during Washington's presidency, plans were made to construct a new capitol in Washington, D.C. Consulting with French engineer Major Pierre L'Enfant, Washington chose the exact site for the construction of the Capitol building. In 1792, Washington held a competition between architects to see who could come up with the best design. After judging William Thornton's as the best, Washington set the cornerstone for the Capitol (with

Masonic rites) in 1793. Construction continued long after Washington retired.

As the nation grew and the number of its representatives in government increased, assemblies outgrew their respective chambers. Consequently, old chambers were reassigned and new chambers were built. For example, the Old Senate Chamber (the first chamber to be completed in 1800) served as a meeting place for the U.S. Senate from 1819 to 1859. After the Senate outgrew it, the U.S. Supreme Court used it from 1860 to 1935. Since that time, the chamber has served as a legislative history museum. At one point, the Capitol building housed the Library of Congress, but the need for more space led to the library's move to three nearby buildings.

During the War of 1812 (1812–1815), British troops set fire to several buildings in Washington, D.C., including the Capitol building. With only the exterior walls left intact after the fire was extinguished by a rain storm, the building was reconstructed in 1827 with a low, wooden dome design. In the late 1850s, new wings were added, which more than doubled the size of building. The expansion gave architects an opportunity to suggest a much larger dome design, because they believed that the old dome no longer suited the larger building's proportions. Congress approved the construction of the new fireproof, cast-iron dome. The cost of the new dome was \$1,047,291 (\$232 million 2015 dollars). It was constructed with 8,909,200 pounds of ironwork bolted together in a way to make it look like the stone in the building.

In 1856, the old dome was removed, and 5 million pounds of new masonry were placed on the existing walls to serve as a foundation for the new dome—which was lifted into place by several steam-powered derricks. Construction of the new dome was still underway during the American Civil War (1861–1865). Some politicians advised President Abraham Lincoln (1809–1865) to halt the costly construction so that the money could be used for the war effort. Lincoln rejected their advice. He explained, “If the people see the Capitol going on, it is a sign that we intend the Union to go on.” Philip Reid, a slave, oversaw the casting of the *Freedom* statue that was mounted on the exterior zenith of the completed dome in 1863.

Besides the dome itself, perhaps the other most impressive architectural achievement of the Capitol building is the rotunda (a circular room 96 feet in diameter and 180 feet in height) under the dome. The rotunda serves as the principal circulation space in the building by connecting all of the major chambers. Throughout the years, the rotunda has been used for important events and ceremonies, including the lying in state of eminent citizens. The rotunda contains statues on the ground level and paintings throughout. *The Apotheosis of Washington*, for example, is a 4,664 square-foot fresco by Constantino Brumidi on the interior high point of the dome. Brumidi's painting contains figures as much as 15 feet high that can be seen in detail from 180 feet below. Washington, the main figure of the painting, is shown rising to heaven surrounded by the personifications of Liberty, Victory, and Fame and by 13 maidens who symbolize the original 13 states.

Besides the new chambers for the Senate and the House of Representatives, other chambers included the Senate Committee Room and the House Committee Room. The building also included the President's Room, which provided a place for the president to stay when he visited the Capitol building, and the National Statuary Hall Collection, which was made up of statues donated by individual states to honor notable people from their respective histories.

In the 1950s, a new front marble façade was added to the five-story Capitol building as well as 102 new rooms (adding about 100,000 square feet) at a cost of \$11.4 million. In 2000, a visitor center was added. By 2008, the Capitol building was 751 feet, four inches long by 350 feet wide, and it contained 16 acres of floor space. At its tallest point (at the tip of the *Freedom* statue), it measured 287 feet, five inches. It includes many rooms besides assembly chambers, including offices, restaurants, and repair shops. There are also tunnels and subway links between the Capitol building and nearby Senate and House office buildings. Instead of being a single building, the Capitol building has been transformed into a cluster of connected buildings.

In 2013, Congress approved another major renovation of the Capitol building. The \$60 million, three-year project focused primarily on repairing 1,300

cracks in the cast-iron dome. In 2017, the Capitol building held the distinction of having the tallest cast-iron dome in the world.

Rolando Avila

See also *Vol. 2, Sec. 2: Empire State Building*

Further Reading

Aikman, Lonnelle. 1991. *We, the People: The Story of the United States Capitol*. Washington, D.C.: U.S. Capitol Historical Society.

Allen, William C. 2001. *History of the United States Capitol: A Chronicle of Design, Construction, and Politics*. Washington, D.C.: U.S. Government Printing Office.

The United States Capitol Complex Virtual Tour. <http://www.virtually-anywhere.com/portfolio/uscapitol/>, accessed August 22, 2018.

U.S. Sanitary Commission (USSC)

The U.S. Sanitary Commission (USSC) was formed in 1861, chiefly to address the health needs of Union soldiers during the Civil War. Thousands of female volunteers raised millions of dollars at “sanitary fairs,” worked as nurses near battlefields, ran army kitchens, and provided housing for disabled or traveling soldiers. This experience of profoundly meaningful service to a nation in crisis positioned some American women to become further engaged in political culture and reform movements.

Henry Whitney Bellows established the Sanitary Commission in June 1861, only weeks after the Civil War (1861–1865) began. Bellows had already helped form the Women’s Central Relief Association but designed the U.S. Sanitary Commission as a more centralized network of wartime volunteers and resources. The USSC was the only private or civilian-run assistance organization recognized by the federal government. In the work of the fledgling Sanitary Commission, Bellows was joined by other notable reformers of the era, including figures such as Frederic Law Olmstead and George Templeton Strong. Louisa May Alcott also threw her support behind the USSC.

Although men controlled the agency at the executive level, women led many commission branches and local affiliates. These Sanitary Commission women delivered direct aid to war casualties, sometimes seeing action at the battlefield. Most women contributed their time and energies as volunteers, while others contributed funding. Over time, some of the women secured state-level jobs as agents of the Sanitary Commission. Through these activities, numerous women emerged as skilled leaders, including Mary Livermore, Abby May, and Louisa Lee Schuyler. Likely the best-known example is Clara Barton, founder of the American Red Cross. In addition, the women of the Sanitary Commission received support from established female leaders in 19th-century American public health such as Dr. Elizabeth Blackwell and Dorothea Dix.

Representatives of the Sanitary Commission stepped in to attend to needs where the Medical Corps of the U.S. Army did not. Nurses were in short supply in the army and were always men, many of whom had little or no training. The USSC trained some women to act as battlefield nurses. The hazards of Civil War combat became so considerable that, before entering battle, soldiers began pinning notes to their uniforms so that in the event of their deaths, their bodies might be easily identified and returned to their loved ones. USSC nurses kept track of these notes and notified families via letters.

Through the labors of the Sanitary Commission, the United States managed to realize alternatives to prior practice regarding the conduct of the war, particularly in relation to soldiers’ needs. With enhanced services, the Sanitary Commission took a more humane approach to the welfare of soldiers, making every attempt to save the lives and, where possible, restore the health of men felled in combat.

The female volunteers of the U.S. Sanitary Commission are remembered for their resourceful approach to patient care, often with quite limited settings and materials. Throughout the war, women improvised environments and supplies for the medical treatment of soldiers. Private homes and public buildings were repurposed as hospitals, particularly in communities that did not already offer medical facilities. Local soldiers’ aid societies often partnered to deliver such services.

As the organization's name implies, the Sanitary Commission's women helped advocate for more hygienic conditions for the treatment of soldiers' injuries and illnesses, following the practices of Florence Nightingale and her Nightingale plan. Part of the Commission's charge was to reduce preventable disease through proper medical precautions and strict standards of cleanliness. The group's members inspected health care facilities and advised on strategies to avoid dietary ailments such as scurvy.

The women of the Sanitary Commission did not confine their activities to emergency medical care. They raised capital to furnish equipment and supplies that soldiers lacked. They searched for missing warriors and those being held as prisoners of war. They contacted families to notify them of the status of their soldiers. When soldiers recovered, Sanitary Commission women worked to help their families reunite and adjust to the changes sustained by soldiers. When soldiers perished, the women were on hand for the burials to acknowledge losses and support mourners.

Women associated with the Sanitary Commission also worked to effect changes in both policy and procedure. For instance, they struggled to remove bureaucratic barriers to the delivery of war relief. They also functioned as champions for the advancement of women. Among their victories in this regard was the securing of pensions for war nurses.

The Sanitary Commission helped mobilize a citizen army during the Civil War. Through their many accomplishments, the workers of the U.S. Sanitary Commission helped the American public understand that women possessed the fortitude and acumen to endure both war and its aftermath. They also demonstrated that local efforts at benevolence and advocacy gained strength through cooperation and coordination via an entity such as the Sanitary Commission. The year after the war, the USSC worked with soldiers, helping them get access to their pensions and back pay. When the USSC disbanded in 1866, women volunteers had raised over \$25 million for its work.

Not all Sanitary Commission women continued in their role as reformers after the Civil War ended, but women who contributed their services to the Sanitary Commission went on to participate in other efforts

intended for the betterment of society, such as the Woman's Christian Temperance (WCTU). They lent their skills and knowledge to social initiatives, ranging from women's suffrage to asylum reform.

Linda S. Watts

See also Civil War Nursing; Dix, Dorothea; Nightingale Plan; *Vol. 1, Sec. 2*: Blackwell, Elizabeth

Further Reading

Attie, Jeanie. 1998. *Patriotic Toil: Northern Women and the American Civil War*. Ithaca, NY: Cornell University Press.

Ginsberg, Judith. 2006. *Civil War Sisterhood: The U.S. Sanitary Commission and Women's Politics in Transition*. Boston: Northeastern University Press.

Ginzberg, Lori. 1990. *Women and the Work of Benevolence: Morality, Politics, and Class in the Nineteenth-Century United States*. New Haven, CT: Yale University Press.

Vulcanization

Vulcanization is a chemical process that strengthens natural rubber. It is named for the Roman god of fire, Vulcan, because heat is the secret to the procedure. Charles Goodyear (1800–1860) developed the process.

Goodyear was born in Connecticut. He worked with his father until their hardware business went bankrupt in 1830. He was a self-taught chemist who began experimenting with rubber in 1834. Natural rubber is sticky and soft. It is resilient and waterproof, but its softness limits its uses.

Goodyear began experimenting with rubber to use as a waterproofing material. He contracted with the U.S. government to waterproof mail carriers' bags in 1837. While rubber does repel water, it gets even softer and stickier in hot temperatures and stiff in cold temperatures. The mailbag treatment failed at high temperatures.

Others at the time were experimenting with strengthening rubber by adding sulfur. Goodyear worked with a man who used to work at a rubber factory, and they discovered that when sulfur was combined with rubber, it

did become more durable and less sticky. Goodyear parted ways with the man and continued to work on his own. He discovered that rubber mixed with sulfur reacted when it was dropped onto a hot stove. He heated the rubber to higher temperatures than others had tried. The rubber became drier but was still elastic. It did not lose its flexibility when cold or its dryness when wet. He named the process “vulcanization.”

Goodyear patented the process in 1844. He combined white lead and sulfur with the rubber. Twenty-five parts rubber, five parts sulfur, and seven parts white lead were heated to temperatures over 200°F. The heat did not destroy the rubber. When this product was applied to fabric or leather and heated, the excess peeled off the fabric. The fabric was stronger and repelled water. Goodyear published *Gum-Elastic and Its Varieties* between 1853 and 1855.

Unfortunately for Goodyear, his process was easy to copy. He had many court battles defending his patent in the United States and Europe. He had to borrow money. More legal disputes and factory problems increased Goodyear’s money problems. He died in 1860 owing thousands of dollars to debtors.

Today, vulcanized rubber is used in a variety of products from tires, hoses, and shoe soles to hard, vulcanized bowling balls.

Linda Briley-Webb

See also Goodyear, Charles

Further Reading

Asimov, Isaac. 1982. *Asimov’s Biographical Encyclopedia of Science & Technology: The Lives & Achievements of 1510 Great Scientists from Ancient Times to the Present*. Garden City, NY: Doubleday.

Goodyear, Charles. 1844. Improvements in the Manner of Preparing Fabrics of Caoutchouc or India Rubber. U.S. Patent 3633.

Walker, Mary (1832–1919)

A surgeon for the Union during the Civil War and the only woman to receive the Congressional Medal of Honor, Mary Edwards Walker was born November 26,

1832, in Oswego Town, New York. Her parents, Vesta Whitcomb and Alvah Walker, held 25 acres of land on which they grew fruits and vegetables for market. The family also kept a library for all five of their daughters to use. As a youth, Walker was interested in Spiritualism and supported abolition, temperance, and women’s rights, including suffrage.

Her parents established a school, which their daughters attended. As a teen, Walker began reading her father’s medical books, which he had amassed in search of robust health. Walker took up teaching as a way of saving money for medical school. In 1853, she enrolled in Syracuse Medical College in Syracuse, New York, one of the few coeducational medical schools in the United States, receiving her MD in 1855. That November, she married former classmate Albert Miller, and the two established a joint medical practice.

In the 1850s, Walker gained renown as a writer of both poetry and prose. Much of her prose focused on the idea that women should wear comfortable clothes. Like French novelist George Sand, Walker wore pants in public for comfort. Walker prided herself for being arrested numerous times for wearing a suit, bow tie, and top hat in public.

Due to Miller’s numerous affairs, Walker left him and established her own medical practice. Although male physicians and army officers discouraged her, Walker volunteered as a surgeon in the Union Army in Washington, D.C., at the start of the Civil War. At first she received no pay, but by 1864, she was named an acting assistant surgeon and assigned to the 52nd Ohio Volunteers at a salary of \$80 a month.

During the course of her work, she met prominent people like reformer Dorothea Dix. Walker received periodic leaves to lecture about her treatment of wounded soldiers. She treated them at several of the major battlefields of the Civil War. At the invitation of Union general Ambrose Burnside, Walker served at Fredericksburg, where she met Walt Whitman.

Walker traveled throughout the front with little regard for safety, and in April 1864, Confederate troops captured and imprisoned her for spying. Four months later, the Confederacy traded Walker in a prisoner exchange. President Abraham Lincoln called Walker to the White House to inquire about her

treatment in captivity. Having served under such dangerous conditions, Walker asked the Union Army for pay and a commission in the army. She received more than \$400 in back pay but no commission; the army was still a man's sphere. At war's end, President Andrew Johnson awarded Walker the Medal of Honor, making her the most highly decorated woman in the Civil War. She was then the most famous woman physician in the United States.

Having seen carnage, Walker had difficulty readjusting to civilian life. In 1866, the Social Science Congress invited Walker to Britain, where she lectured to large crowds on topics ranging from wartime service to suffrage to dress reform. She was elected president of the National Dress Reform Association in 1866.

Returning to the United States, she mounted a nationwide lecture tour in 1869, campaigning zealously for women's rights. To further the cause, Walker ran for Congress in 1890 and later for U.S. Senate, though she did not win either election. Though she wrote books about women's rights and attended suffrage conventions, she disagreed with Susan B. Anthony and Elizabeth Cady Stanton, leaders of the movement, on how suffrage ought to be achieved. Anthony and Stanton were demonstrating for a constitutional amendment; Walker, however, felt that the Constitution already granted women the right to vote as citizens and Congress only need enact enabling legislation.

In 1917, Congress revised the Medal of Honor standards to include only "actual combat with an enemy" and took Walker's Congressional Medal, along with the medals of 910 others, away. In 1977, President Jimmy Carter had it reinstated.

Walker died on February 22, 1919, in Oswego Town, one year before women gained the right to vote through the ratification of the 19th Amendment.

Christopher Cumo

See also Dix, Dorothea

Further Reading

Coe, Alexis. 2013. "Mary Walker's Quest to Be Appointed as a Union Doctor in the Civil War." *The Atlantic*, February 7. <http://www.theatlantic>



Abolitionist, women's rights activist, and Civil War surgeon Mary Walker is the only woman to have ever been awarded the Medal of Honor, the United States's highest military award. Walker was arrested several times for dressing in men's clothing, though she always said she wasn't wearing men's clothes, but "my own clothes." (National Library of Medicine)

.com/sexes/archive/2013/02/mary-walkers-quest-to-be-appointed-as-a-union-doctor-in-the-civil-war/272909/, accessed August 22, 2018.

Fitzgerald, Stephanie. 2009. *Mary Walker: Civil War Surgeon and Feminist*. Minneapolis: Compass Point Books.

Harris, Sharon M. 2009. *Dr. Mary Walker: An American Radical, 1832–1919*. New Brunswick, NJ: Rutgers University Press.

Western Union Telegraph Company

The telegraph had been evolving since the 1830s; it was the confluence of many electromagnetic experiments and inventions. In England, William Cooke and Charles Wheatstone constructed a one-mile telegraph line in 1837. The first practical telegraph was demonstrated at the Great Exhibition of 1851 in London. Its earliest use was to carry news of events. At about the same time in the United States, Samuel Morse was developing an improved telegraph using the new electromagnets of Joseph Henry. Morse added battery relays to greatly increase the distance of the Cooke and Wheatstone system. Just as important was Morse's addition of a binary code using dots and dashes to spell out words. The dots and dashes were audio signals using a sound key to produce a "click." By 1840, Morse's system had a 10-mile range. Congress had originally funded the first telegraph line between Baltimore and Washington, D.C., in 1843 in hopes of combining it into the postal system. Congress appropriated \$30,000 for the construction of a 38-mile line along the Baltimore and Ohio Railroad. Congress, however, refused further funding for the telegraph postal service and purchase of the patent rights from Morse. This opened the technology to the private sector. Morse formed the Magnetic Telegraph Company of 1845. Morse built a highly profitable line connecting Washington, D.C., and New York with the help of Ezra Cornell. Cornell (founder of Cornell University) was the inventor of the trench digger. The Magnetic Telegraph Company had started to use underground cable but soon switched to poles to save money and speed up construction. Even though underground cable had failed, Cornell proved the better manager and took over the company.

Additional private companies extended lines to Pittsburgh, Cincinnati, and Louisville. The Morse patents licensed most of the small companies. The newspapers were the first to make the telegraph profitable and caused its rapid expansion. In 1847, the battles of the Mexican-American War were transmitted to waiting reporters across the nation. President James K. Polk's State of the Nation address was carried directly via telegraph in 1848. In Europe, Reuters News used carrier pigeons to carry financial messages between telegraph lines and expand across Europe. In America, the

parent company of Western Union would be the New York & Mississippi Printing Telegraph Company, created in 1851. The name comes from the fact that the first telegraphs printed the Morse code on paper, but the audio system was quickly accepted. A good operator could send 8 to 10 words a minute. The company started to buy out and merge with smaller companies with a vision of creating a fully integrated national service.

The telegraph spread as competing companies set up their own lines. Two major East Coast companies were the New York & Mississippi Printing Telegraph Company of Hiram Sibley and the New York & Western Union Telegraph Company of Cornell. Sibley decided that it was cheaper to buy up smaller companies than to build new lines. This type of business model would be repeated by railroads, telephone companies, and, more recently, cell phone companies. Sibley also decided to standardize all service on the use of the Morse code. The spread of the telegraph augured the business model of the telephone and cell phone markets. The larger companies soon realized the advantages of merging to build even larger markets and gain economies of scale and effort. To that end, the East Coast competitors merged in 1855 to form the Western Union Telegraph Company. The next phase of innovation was, as for all inventions, cost reduction. The major cost of the telegraph was in the iron wire connections on miles of poles, which inspired cost-saving inventions. J. B. Stearns invented a relay sensing system in 1858 that allowed two messages, one in each direction, over a single wire.

As railroads expanded, the use of the telegraph avoided railroad crashes and facilitated switching on the then one-way tracks. The railroad right-of-ways also provided land for the spread of the telegraph. Business created demand for the telegraph as well. Businessmen could now be connected to the markets in New York and their operations in other cities. Bankers were also early adopters of the telegraph. Initially, telegraphs were at rail stations in major cities. Once an operator decoded a message, boys then ran the messages to business offices. Many famous businessmen and inventors, such as Andrew Carnegie and Thomas Edison, started as telegraph operators and messengers. The Civil War created even more demand for the telegraph. President Abraham Lincoln used it to send his

1860 call for troops to governors. During the war, Lincoln was like a teenager with a cell phone, hanging out at the White House telegraph station for news of the war. Union generals quickly adopted the telegraph as a means of communication. During the Civil War, an estimated 6 million messages were sent using 1,500 telegraph operators. The first transcontinental telegraph system was established in 1861 by connecting smaller services across the West to a line through Alaska to Moscow. The transcontinental line was sponsored and funded by the U.S. Congress because no company had the necessary funds for such a large project. Western Union did win the bid to build it. By the end of the war, there were over 200,000 miles of telegraph in operation.

In 1866, Western Union completed the first stock ticker service, which proved to be a highly profitable business. The first successful transatlantic telegraph cable was completed on July 27, 1866. In 1871, Western Union continued its horizontal integration with new businesses with a money transfer service. Now banks could “wire” funds across the country rapidly. In 1884, Western Union became one of the 11 original American companies to be tracked in the Dow Jones stock average. Eventually, Western Union absorbed over 500 companies to become a major corporate giant by 1890. In the 1870s, Western Union tried to defend itself against the telephone by entering the business, hoping to utilize its wired infrastructure. Alexander Bell’s patent challenges prevented Western Union from entering the telephone business, however. As the telephone took over, Western Union focused on its money transfer business. Western Union was considered one of the first industrialized monopolies and was able to merge into the telephone business, which was also dependent on electrical wires. In 1908, Western Union was briefly absorbed into the American Telephone and Telegraph Company (AT&T). The government would use antitrust laws to force the two to separate.

Quentin R. Skrabec

See also Transatlantic Cable

Further Reading

Kranzberg, Malven, and Carroll Pursell Jr. 1967. *Technology in Western Civilization*. New York: Oxford University Press.

Thompson, Robert Luther. 1972. *Technology and Society*. New York: Arno.

Winston, Brian. 1998. *Media Technology and Society: A History: From the Telegraph to the Internet*. London: Routledge.

Zipper

Tied ribbons, buttons, hooks and eyes, and snaps were earlier ways to fasten things together until the invention of the zipper, credited to several different men over a span of years.

In 1851, Elias Howe, who had previously invented the sewing machine, received a patent for what he called an “Automatic, Continuous Clothing Closure.” Too busy promoting the sewing machine, he ignored his own new invention. In 1893, Whitcomb Judson designed a fastener for shoes that he called the “Clasp Locker,” and he started the Universal Fastener Company to facilitate mass production. The product debuted at the 1893 World’s Fair in Chicago, but customers did not flock to it.

Gideon Sundback, Judson’s employee at the Universal Fastener Company, received a patent for his version, the “Separable Fastener,” in 1917. His improvements to earlier designs included two rows of interlocking teeth that latched together with the help of a slider, the most similar design to what is used in the current day.

Finally, the B. F. Goodrich Company used Sundback’s device as a fastener on a new type of rubber boots and was the first to call the device a “zipper.” Early on, zippers were mainly used on boots and tobacco pouches, but within 20 years, the fashion industry began to use zippers on clothing, particularly to replace the buttons on men’s trousers.

Rosanne Welch

See also Howe, Elias

Further Reading

Petroski, Henry. 1994. *The Evolution of Useful Things: How Everyday Artifacts—From Forks and Pins to Paper Clips and Zippers—Came to Be as They Are*. New York: Vintage.

Bibliography: Colonial America to 1865

Section 1: Colonial America and Enlightenment Science

- Asimov, Isaac. 1982. *Asimov's Biographical Encyclopedia of Science & Technology: The Lives & Achievements of 1510 Great Scientists from Ancient Times to the Present*. Garden City, NY: Doubleday.
- Cerami, Charles A., and Robert M. Silverstein. 2002. *Benjamin Banneker: Surveyor, Astronomer, Publisher, Patriot*. New York: John Wiley and Sons.
- Dinkelspiel, Frances. 2010. *Towers of Gold: How One Jewish Immigrant Named Isaias Hellman Created California*. New York: St. Martin's Press.
- Franklin, Benjamin, and Bob Blaisdell. 2013. *Poor Richard's Almanack and Other Writings*. New York: Dover.
- Hibbeler, Russell Charles. 1983. *Engineering Mechanics-Statics*. 3rd ed. New York: Macmillan.
- Houston, Keith. 2016. *The Book: A Cover-to-Cover Exploration of the Most Powerful Object of Our Time*. New York: W. W. Norton.
- Isaacson, Walter. 2003. *Benjamin Franklin: An American Life*. New York: Simon & Schuster.
- Lee, Mike. 2017. *Written Out of History: The Forgotten Founders Who Fought Big Government*. New York: Sentinel.
- Miller, Perry. 1981 [1953]. *The New England Mind, from Colony to Province*. Cambridge, MA: The Belknap Press of Harvard University Press.
- Rothenstein, Richard. 2017. *The Color of Law: A Forgotten History of How Our Government Segregated America*. New York: Liveright.
- Sullivan, J. 2006. *Jeans: A Cultural History of an American Icon*. New York: Gotham Books.

Swanson, June. 1991. *David Bushnell and His Turtle: The Story of America's First Submarine*. New York: Atheneum Press.

Wallace, Gusler. 2003. *Three Centuries of Tradition: The Renaissance of Custom Sporting Arms in America*. Minneapolis: Minneapolis Institute of Arts.

Winslow, Ola. 1974. *A Destroying Angel: The Conquest of Smallpox in Colonial Boston*. Boston: Houghton-Mifflin.

Section 2: The New Republic and the Market Economy (1780–1820)

- Ambrose, Stephen. 1997. *Undaunted Courage: Meriwether Lewis, Thomas Jefferson, and the Opening of the American West*. New York: Simon & Schuster.
- Bernstein, Peter. 2005. *The Wedding of the Waters: The Erie Canal and the Making of a Great Nation*. New York: W. W. Norton.
- Boyd, Julia. 2005. *The Excellent Doctor Blackwell: The Life of the First Female Physician*. Stroud, UK: Sutton.
- Carter, Gregg Lee, ed. 2012. *Guns in American Society: An Encyclopedia of History, Politics, Culture and the Law*. Santa Barbara, CA: ABC-CLIO.
- Cohen, Bernard. 1995. *Science and the Founding Fathers: Science in the Political Thought of Thomas Jefferson, Benjamin Franklin, John Adams and James Madison*. New York: W. W. Norton.
- Ganesan, V. 2012. *Internal Combustion Engines*. Mumbai: McGraw Hill Education (India) Pvt.
- Hills, Richard. 2000. *Power from Steam: A History of the Stationary Steam Engine*. Cambridge: Cambridge University Press.

- James, Ioan. *Remarkable Physicists From Galileo to Yukawa*. Oxford: Cambridge University Press, 2004.
- McCullough, D. 2012. *The Great Bridge: The Epic Story of the Building of the Brooklyn Bridge*. New York: Simon and Schuster.
- Rosen, William. 2010. *The Most Powerful Idea in the World: A Story of Steam, Industry and Invention*. New York: Random House.
- Sale, Kirkpatrick. 2001. *The Fire of His Genius: Robert Fulton and the American Dream*. New York: Free Press.
- Thornton, Tamara Platkins. 2016. *Nathaniel Bowditch and the Power of Numbers: How a Nineteenth-Century Man of Business, Science, and the Sea Changed American Life*. Chapel Hill: The University of North Carolina Press.
- Ulrich, Laurel Thatcher. 1990. *A Midwife's Tale; The Life of Martha Ballard Based on Her Diary 1785–1812*. New York: A. Knopf.
- Whitney, Eli. 2012. *Memoir of Eli Whitney, Esq.* Edited by Denison Olmstead. London: Forgotten Books.
- Wright, Kevin W. 2016. *The Morris Canal and the Age of Ingenuity: Climbing Mountains to Solve America's First Energy Crisis*. Charleston, SC: America Through Time.
- Zonderman, David A. 1992. *Aspirations and Anxieties: New England Workers and the Mechanized Factory System, 1815–1850*. New York: Oxford University Press.
- Section 3: Antebellum Industrialization and the Civil War (1820–1865)**
- Adams, Sean P. 2014. *The American Coal Industry, 1790–1902*. London: Pickering & Chatto.
- Allen, William C. 2001. *History of the United States Capitol: A Chronicle of Design, Construction, and Politics*. Washington, D.C.: U.S. Government Printing Office.
- Bell, Ryan Corbett. 2012. *A History of the Ambulance*. Reprint ed. Jefferson, NC: McFarland.
- Bergland, Rene. 2008. *Maria Mitchell and the Sexing of Science: An Astronomer Among American Romantics*. New York: Beacon Press.
- Bianculli, Anthony J. 2008. *Iron Rails in the Garden State: Tales of New Jersey Railroading*. Bloomington: Indiana University Press.
- Bilby, Joseph G. 1996. *Civil War Firearms: Their Historical Background and Tactical Use*. Cambridge: De Capo Press.
- Bise, C. J. 2013. *Modern American Coal Mining: Methods and Applications*. Englewood, CO: Society for Mining, Metallurgy, and Exploration.
- Casson, Herbert Newton. 2005. *Cyrus Hall McCormick: His Life and Work*. New York: Cosimo Classics.
- Coggins, Jack. 2004. *Arms and Equipment of the Civil War*. Mineola, NY: Courier Dover.
- Cookson, Gillian. 2013. *The Cable Wire to the New World*. Stroud, UK: History Press.
- Creighton, Jeff. 1996. *Combines and Harvesters: Photographic History*. Osceola, WI: Motorbooks.
- Evans, Harold, Gail Buckland, and David Lefer. 2004. *They Made America: From the Steam Engine to the Search Engine: Two Centuries of Innovators*. Boston: Little, Brown.
- Fitzgerald, Stephanie. 2009. *Mary Walker: Civil War Surgeon and Feminist*. Minneapolis: Compass Point Books.
- Geier, Clarence R., Douglas D. Scott, and Lawrence E. Babits. 2014. *From These Honored Dead: Historical Archaeology of the American Civil War*. Gainesville: University Press of Florida.
- Gill, Gillian Catherine. 2004. *Nightingales: The Extraordinary Upbringing and Curious Life of Miss Florence Nightingale*. New York: Random House.
- Gordon, John Steele. 2003. *A Thread Across the Ocean: The Heroic Story of the Transatlantic Cable*. New York: HarperCollins.
- Haller, John S., Jr. 2011. *Battlefield Medicine: A History of the Military Ambulance from the Napoleonic Wars through World War I*. Carbondale: Southern Illinois University Press.
- Hearn, Chester G. 2004. *Circuits in the Sea: The Men, the Ships, and the Atlantic Cable*. Westport, CT: Praeger.
- Hennessy, Kathryn, ed. 2012. *Fashion: The Definitive History of Costume and Style*. New York: DK.

- Hilde, Libra R. 2012. *Worth a Dozen Men: Women and Nursing in the Civil War South*. Charlottesville: University of Virginia Press.
- Holler, Sherman, ed. 2013. *Pioneers of the Industrial Age Breakthroughs in Technology*. New York: Encyclopedia Britannica.
- Houston, Keith. 2016. *The Book: A Cover-to-Cover Exploration of the Most Powerful Object of Our Time*. New York: W. W. Norton.
- Kirby, Richard Shelton, Sidney Withington, Arthur Burr Darling, and Frederick Gridley Kilgour. 1990. *Engineering in History*. New York: Dover.
- Mabee, Carleton. 2000. *The American Leonardo: A Life of Samuel F. B. Morse*. New York: Purple Mountain Press.
- Macmillan, Don. 2014. *The Bigger Book of John Deere: The Complete, Model-by-Model Encyclopedia*. McGregor, MN: Voyageur Press.
- McGaw, Judith A. 1994. *Early American Technology. Making & Doing Things from the Colonial Era to 1850*. Chapel Hill: University of North Carolina Press.
- Muir, Diana. 2000. *Reflections in Bullough's Pond*. Hanover, NH: University Press of New England.
- Nightingale, Florence. 2013. *Notes on Nursing: What It Is and What It Is Not*. New York: Creative Space.
- Peavitt, Helen. 2017. *Refrigerator: The Story of Cool in the Kitchen*. London: Reaktion Books.
- Peres, Michael R. 2007. *The Focal Encyclopedia of Photography: Digital Imaging, Theory and Applications, History, and Science*. New York: Focal Press.
- Perkins, Thomas A. 2016. *Jacob Perkins of Wells Maine and His Descendants, 1583–1936*. Boston: Facsimile.
- Petroski, Henry. 1994. *The Evolution of Useful Things: How Everyday Artifacts—From Forks and Pins to Paper Clips and Zippers—Came to Be as They Are*. New York: Vintage.
- Rutkow, Ira M. 2005. *Bleeding Blue and Gray: Civil War Surgery and the Evolution of American Medicine*. New York: Random House.
- Sanders, Ralph W. 2001. *Ultimate John Deere, The History of the Big Green Machines*. Stillwater, OK: Voyageur Press.
- Schultz, Jane E. 2004. *Women at the Front: Hospital Workers in Civil War America*. Chapel Hill: University of North Carolina Press.
- Shiva, Vandana. 2016. *Who Really Feeds the World: The Failures of Agribusiness and the Problems of Agroecology*. Berkeley, CA: North Atlantic Books.
- Solomon, Brian. 2014. *North American Railroads: The Illustrated Encyclopedia*. Stillwater, OK: Voyageur.
- Standage, Tom. 1998. *The Victorian Internet: The Remarkable Story of the Telegraph and the Nineteenth Century's On-Line Pioneers*. New York: Walker & Walker.
- Sykes, Keith. 2007. *Anaesthesia and the Practice of Medicine: Historical Perspectives*. Boca Raton, FL: CRC Press.
- Toler, Pamela D. 2017. *Heroines of Mercy Street: Real Nurses of the Civil War*. Boston: Back Bay Books, Media Tie In edition.
- Wiatrowski, Claude A. 2012. *Railroads across North America: An Illustrated History*. Sarasota, FL: Crestline.
- Wilson, Jeff, ed. 2014. *The Historical Guide to North American Railroads*. Waukesha, WI: Kalmbach.
- Wolmar, Christian. 2013. *The Great Railroad Revolution: The History of Trains in America*. New York: PublicAffairs.

Index

Boldface numbers refer to volume numbers.

- Abbe, Cleveland (1838–1916), **2**:7–9
 Monthly Weather Review founded by, **2**:8
 National Geographic Society cofounder, **2**:8
- Abbott, John G., **1**:210–211
- Abbott Laboratories, **1**:179
- AC generator and transformer, **2**:9–10
 at Chicago World’s Columbian Exposition, **2**:58, 63, 107
 Great Barrington Electrification, **2**:9, 62
 primary document: AIEE biography for William Stanley (1934), **2**:10
 and “war of the currents,” **2**:9, 58, 62–63
- AC induction motor, **2**:10–11, 148
 primary document: Tesla’s patent (1896), **2**:11–14
- Acetylsalicylic acid. *See* Aspirin
- Acquired immune deficiency syndrome (AIDS). *See* AIDS research
- Adams, Ansel, **2**:293; **3**:80
- Adams, John, **1**:8, 10, 144, 260
- Adams, Thomas, **2**:157, 210
- Addams, Jane, **2**:172
- Adding machine with keys, **2**:14, 114
- Adding machines, **2**:14, 113–114
 Arithmometer, **2**:113–114
 automatic calculation, **1**:113–114
 clearing lever (“machine gun of the office”), **2**:114
 Comptometer, **2**:113–114
 Dalton Adding Machine (10 numerical buttons), **2**:114
 and industrialization of leisure, **2**:5
 and paper copies of tabulations, **1**:114
 See also Calculators
- Additive manufacturing. *See* 3-D printing
- Adhesive bandages, **2**:185. *See also* Band-Aid
- Adhesive tape, **1**:174–175
 Band-Aid, **1**:175; **2**:175, 185
 duct tape, **1**:175; **2**:256
 masking tape, **1**:175; **2**:113, 218, 241
 Scotch Tape (cellophane tape), **2**:113, 218, 241, 253
 as staple in American homes, **2**:253
 uses for, **1**:175
- Advanced Research Projects Agency Network. *See* ARPANET
- Aerosol spray can, **2**:176
- Aerosols
 and carbon capture and storage (CCS), **3**:40
 and chlorofluorocarbons (CFCs), **2**:176; **3**:38
 and Clean Air Act (1977), **2**:176
 definition of, **2**:176
 and Freon, **2**:205
- Agassiz, Elizabeth Cabot Cary, **1**:176, 259
 American Philosophical Society member, **1**:9
 Louis Agassiz: His Life and Correspondence, **1**:176–177
- Agassiz, Louis (1807–1873), **1**:46, 175–176
 primary document: excerpt from journal (1846), **1**:176–177
- Age of Reason. *See* Enlightenment
- Agent Orange, **3**:9–10
 discontinuation of use of, **3**:7
 naming of, **3**:9
 Operation Pacer IVY (removal of barrels from Vietnam), **3**:10
 producers of, **2**:50; **3**:9
 protests against, **3**:7
 toxicity and health effects of, **3**:9–10
- AI. *See* Artificial intelligence (AI)
- AIDS research, **3**:171–173
 AZT (zidovudine, drug treatment), **3**:172, 197
 discovery of HIV, **3**:172
 Doha declaration, **3**:172
 ELISA blood test, **3**:172
 first verified HIV case, **3**:171
 highly active antiretroviral therapy (HAART), **3**:172
 history of HIV/AIDS, **3**:171
 HIV mutations, **3**:173
 and Kaposi’s sarcoma, **3**:171, 173
 and medical technology, **3**:249
 and National Institutes of Health, **2**:105; **3**:173, 175
 and pneumocystis carinii pneumonia (PCP), **3**:171, 173
 prevention of HIV transmission, **3**:172
 primary document: introduction to AIDS archive by C. Everett Koop, **3**:173–177
 rapid HIV tests, **3**:172, 249
 and research by Salk, Jonas, **3**:126
 saquinavir (drug treatment), **3**:172

- “Air” athletic shoes, 3:11
- Airplane, 2:176–177
- airmail delivery, 2:255–256
 - contribution to decline in railroad ridership, 1:290–291
 - helicopter compared with, 2:276
 - history of, 2:176
 - and internal combustion engines, 1:120
 - and mass production, 1:75
 - first international flights (Pan American), 2:178
 - first powered, controlled aircraft (Wright brothers), 2:7, 164–166, 170–171, 178, 312
 - first transatlantic flight (Charles Lindbergh), 2:175
 - and military-industrial complex, 3:89, 90
 - NASA’s research benefits for, 3:95
 - and National Advisory Committee for Aeronautics (NACA), 2:223
 - and Pauling oxygen meter, 3:111
 - and stealth technology, 3:138–139
 - submerged airplane retrieval systems, 2:319
 - in Vietnam War, 3:9–10
 - and Whiton Centering Machine, 1:67
 - in World War I, 2:75, 171, 176, 178, 234; 3:48
 - in World War II, 2:189, 223, 234, 255–256, 261–262, 300, 301; 3:7
- See also* Drones
- Airplane deicer, 2:189; 3:254–255
- Alaska Highway, 2:257–260
- environmental effects of, 2:258–259
 - primary document: excerpt from Ruth Gruber’s study of highway routes to Alaska (1941), 2:259–260
- Alcott, Bronson, 1:168
- Alcott, Louisa May, 1:191, 306
- Alcott, William Andrus, 1:236
- Alexander, Edward Porter, 1:186
- Allen, Horatio, 1:181
- Allen, Paul, 3:199–200, 217
- Allestree, Richard, 1:11
- Almanacs. *See* Astronomical almanacs
- Almy, Brown, and Slater, 1:101, 147
- Almy, William, 1:101, 146–147
- Amalgamated Clothing Workers of America (ACWA), 2:14–16
- commitment to “new unionism,” 2:14
 - and formation of Congress of Industrial Organizations (CIO), 2:15
- See also* Labor and labor unions
- Amazon Web Services, 3:255–256, 258
- central hubs, 3:255
 - popular services, 3:255
 - users, 3:250, 255
- Amazon.com, 3:256–258
- acquisitions, 3:257, 266
 - Amazon Prime, 3:258
 - Kindle e-book reader, 3:251, 258, 265, 312
 - history of, 3:256–258
 - influence of, 3:247, 256
 - Linux’s influence on, 3:318
 - as tech start-up, 3:166, 301
 - video streaming, 3:323
- American Academy of Arts & Sciences, 1:73
- American Philosophical Society (APS), 1:8–10
- and Franklin, Benjamin, 1:4, 8–10, 45, 71–72
 - grants program, 1:9
 - and Jefferson, Thomas, 1:4, 8–9, 45, 158
 - Lewis and Clark Expedition sponsor, 1:124, 125
 - library and museum, 1:9–10
 - members, 1:8–9, 45, 46
 - and natural history movement, 1:78
 - origin and goals, 1:8, 45
 - primary document: APS’s favoring exploration of the Alaskan coast (1868), 1:10–11
 - publications program, 1:10, 97
 - sponsor of Lewis and Clark Expedition, 1:45, 124, 125
 - sponsor of Rittenhouse, David, 1:45
- American Telephone and Telegraph Company (AT&T), 2:16–17
- acquisitions of Time Warner and DirecTV, 2:17
 - AT&T Mexico, 2:17
 - Audion (triode) rights sold to, 2:196, 246
 - Bell Labs established by, 2:186, 324
 - Clarke, Edith, at, 2:268
 - court-ordered dismantling of, 2:17, 325
 - declared a monopoly by Department of Justice, 2:16, 17, 325
 - established by National Bell Telephone Company, 2:16, 27, 324
 - first long-distance lines of, 2:16
 - first undersea cable installed by, 2:16
 - Holmes Electric Protective Company purchased by, 1:183
 - innovations of, 2:16–17
 - and television technology, 2:17, 326
 - and Western Electric (subsidiary), 2:186
 - and Western Union, 1:311
 - and World War I, 2:16
 - and World War II, 2:17
- See also* Bell Telephone Laboratories
- Ames, Nathaniel, 1:11–12
- Amino acids, 3:5. *See also* DNA (deoxyribonucleic acid)
- Amphibious steam vehicle, 1:79–81
- Oruktor Amphibolos*, 1:79–81, 107, 118
 - primary document: image of amphibious steam vehicle (1834), 1:81
- Anderson, Herbert, 2:272
- Anderson, James, 1:302
- Anderson, Mary (1866–1953), 2:179
- Anderson, Paul Thomas, 3:135
- Anderson, Robert, 3:50

- Anesthesia, 1:178–179
 chloroform, 1:179, 256
 “ether frolics,” 1:178
 nitrous oxide, 1:178, 202, 203, 246–247
 sulfuric ether, 1:246–247
 types of, 1:178; 247
- Antebellum Industrialization and the Civil War (1820–1865), 1:167–174
 abolition movement, 1:171–172
 agricultural innovation, 1:171–172
 communication innovations, 1:169
 early women’s rights movement, 1:170, 172
 economic depression, 1:167, 171, 232
 education, 1:169–170
 financial panic of 1837, 1:167, 204, 217
 impact of electronic telegraph, 1:167
 industrial advancements, 1:168–169
 institutional reform, 1:167
 laissez-faire, free-market economics, 1:167, 171
 Jacksonian democracy, 1:167
 Patent Act of 1836, 1:170
 population increases, 1:167
 Second Great Awakening, 1:168, 235–236
 Transcendental Movement, 1:168, 170, 171
- Antiballistic missiles (ABMs), 3:11–12
 and Anti-Ballistic Missile Treaty (1972), 3:12, 239–240
 Strategic Defense Initiative (SDI or “Star Wars”), 3:12, 90, 239–240
- Antibiotic, 3:13–14
 antibiotic-resistant GM species, 3:271
 and cattle, 2:145
 chloramphenicol, 3:5
 development of trimethoprim, 3:196
 importance of, 3:5, 300–301, 306–307
 nystatin, 3:5, 13–14
 penicillin, 2:6, 256–257, 300–301, 306–307; 3:5, 13
 and resistant bacteria, 2:306
- Antibiotic bandages, 2:185
- Apple, 3:177–179
 Apple TV, 3:323
 competition with IBM, 3:177
 controversy and criticism, 3:178–179
 educational marketing campaign, 3:177
 Facebook App, 3:269
 Google as Safari’s default search engine, 3:253
 HyperCard, 3:190
 iCloud, 3:178, 211
 iMac, 3:178, 198
 iPad, 3:178, 180, 153, 209, 211–212
 iPhone, 3:178, 179, 180, 209, 219, 211–212, 219, 251, 269, 311–312
 iPod, 3:121, 178, 180, 209, 211–212, 251, 286, 298–299, 311
 iTunes, 3:178, 188, 209, 252, 286, 299, 308, 311
- Lisa, 3:177
- Macintosh, 3:165, 177–178, 209–210, 212, 213, 245
- Microsoft programs for, 3:200
- NeXT acquired by, 3:178
- and open-source movement, 3:221–222
- and portability, 3:253–254
- Power Macintosh (Power Mac), 3:178
- PowerBook, 3:178
- Quick Take, 2:57; 3:194
- ROKR, 3:311
- Swift coding language, 3:222
- and touch screen technology, 3:251
- and Trinity of computers, 3:223
- See also* Jobs, Steve; Wozniak, Steve
- Apple I, 3:177, 209–210, 244
- Apple II, 3:179–180
 BASIC programming language, 3:179, 244
 color monitor, 3:179, 223
 competition with Commodore, 3:179, 224
 competition with IBM, 3:205, 206
 competition with Radio Shack, 3:179
 cost, 3:180, 223
 and Dell, Michael “Saul,” 3:192–193
 mouse-central interfact, 3:159
 open architecture system, 3:42, 180
 success and importance of, 3:177, 180, 205, 209–210, 223, 244
 user-friendliness, 3:179–180, 209–210, 223
 and *VisiCalc*, 3:180, 206, 224
- Apple IIc, 3:165
- Apple III, 3:177
- Apple parers, 1:82–83
- Appleby, John, 1:304
- Apollo Project, 3:14–16
 Apollo 1, 3:15
 Apollo 8, 3:63
 Apollo 11, 3:4, 15, 63, 76, 95
 Apollo 13, 3:15
 Apollo-Soyuz Test Project, 3:4
 and Comsat/Intelsat, 3:42
 cost of, 3:14, 15
 criticism of, 3:15, 237
 and Fairchild Semiconductors, 3:131–132
 goal of, 3:14, 95
 and Hamilton, Margaret, 3:62–63
 and *Hidden Figures* (film), 3:74
 and Johnson, Katherine Goble, 3:76, 155
 largest scientific U.S. program, 3:14
 and lunar surface samples, 3:15–16
- Nike Air Tailwind, 3:11
- and Skylab, 3:133–134
- and Space Race, 3:14–15
- termination of, 3:16, 237

- Apollo Applications Program (AAP), 3:133
- Apollo telescope mount (ATM), 3: 97, 3:133
- Argenti, Felice, 1:172
- Arithmometer, 2:113–114. *See also* Adding machines
- Arkwright, Richard, 1:101, 146, 147
- Armstrong, Edwin Howard, 2:246, 272
- Armstrong, Neil, 3:4, 15, 95
- Arnold, H. H. “Hap,” 2:261, 331–332
- ARPANET, 3:16–18
- and Defense Advanced Research Projects Agency (DARPA), 3:2–3, 16, 208
 - and first e-book, 3:264
 - first email sent, 3:17
 - as forerunner to the Internet, 3:2–3, 16, 164, 190, 208, 300, 329
 - funding for, 3:16
 - and Metcalfe, Robert, 3:214
 - origins of, 3:16–17, 300
 - and packet switching, 3:17, 107
- Artificial heart, 3:180–181, 238
- Artificial intelligence (AI), 3:181–183
- AI effect, 3:183
 - approaches to, 3:181–182
 - definition of, 3:181
 - ethical concerns of, 3:183
 - future evolutions of, 3:190–191
 - and fuzzy logic systems, 3:182
 - implementation of at system level, 3:183
 - and Minsky, Marvin, 3:90–91
 - predicted by Kurzweil, Ray, 3:292
 - problems in creation of, 3:181
 - and statistics, 3:182
 - TensorFlow (Google), 3:222
- Artificial memories, 3:258–259
- Aspartame, 3:18–19
- NutraSweet (brand name), 3:18–19
 - public health concerns, 3:19
 - and saccharine, 2:137; 3:18–19
- Asphalt, 2:17–18
- invention of modern road asphalt, 2:17
 - natural asphalt (La Brea Tar Pits), 2:18
 - used for Alaska Highway, 2:258
- Aspirin, 2:18–19
- Assembly line, 2:179–181
- automated flour mill’s influence on, 1:107
 - conveyer system, 2:180
 - and crayons, 2:46
 - and Ford, Henry, 2:170, 179–180, 182, 203, 204; 3:49
 - history and invention of, 2:179
 - and interchangeable parts, 1:118, 119
 - and liberty ships, 2:294
 - moving chassis, 2:180, 182
 - myth of invention by Ford, Henry, 2:179
 - and Olds, Ransom Eli, 2:225
 - primary document: excerpt from Henry Ford’s “The First Assembly Line” (1913), 2:181
 - stationary, 2:225
 - supply chain development, 2:180
- Association for Women in Mathematics (AWM), 3:19–20
- Astor, John Jacob, IV, 2:2, 107
- Astronomical almanacs, 1:11–12
- An Almanac for New England for the Year 1639* (first American almanac), 1:11
 - Astronomical Diary and Almanack* (Ames’s *Almanack*), 1:11, 12
 - The Old Farmer’s Almanac*, 1:11
 - Pennsylvania, Delaware, Maryland and Virginia Almanack and Ephemeris*, 1:15
 - Rhode-Island Almanack*, 1:11, 15
 - Poor Richard’s Almanack*, 1:11, 12, 13, 26
 - Poor Robin’s Almanack*, 1:11
 - primary document: aphorisms from *Poor Richard’s Almanack* (1732–1758), 1:13
- AT&T. *See* American Telephone and Telegraph Company
- Atari, 3:20–22, 132
- home computers, 3:20, 22
 - Jobs, Steve, game designer at, 3:209, 244
 - lawsuit and intellectual property rights, 3:22
 - Pong*, 3:20, 21–22, 119–120, 321
 - success of, 3:20–22, 321
 - virtual reality version of, 3:323
- Atomic bombs/nuclear weapons, 2:260–261
- Fat Man and Little Boy (atomic bombs dropped on Japan), 2:261, 297
 - Hiroshima and Nagasaki attacks, 2:260–261, 272, 283, 297, 300, 303; 3:220
 - history of, 2:260
 - Trinity test (first U.S. nuclear test), 2:260, 272, 297, 303
 - See also* Manhattan Project
- Automobile technologies (pre–World War II), 2:181–183
- assembly line, 2:179–181, 182, 203, 204
 - “Big Three” U.S. automobile makers, 2:183
 - closed-body cars, 2:182
 - company competition, 2:182
 - fenders, 2:181, 183
 - Great Depression’s effect on, 2:182
 - hydraulic brakes, 2:181, 182
 - reinforced glass, 2:182–183
 - transitional phase, 2:181
 - V8 engine, 2:181, 182
 - Vintage Era, 2:181–183
 - Y Job fender, 2:183
- Automotive technologies (post–World War II), 3:22–24
- automatic transmissions, 3:23
 - battery and energy storage technologies, 3:23
 - “Big Three” U.S. automobile makers, 3:22
 - and dynamic obsolescence, 3:22
 - electric vehicles (EVs), 3:23, 49–53, 247, 281

- electronic and computer systems, 3:23
- and Federal-Aid Highway Act (1956), 3:23
- and government regulations, 3:23
- hybrid-electric vehicles (HEVs), 3:23, 49–53, 247, 281–283
- independent suspensions, 3:23
- and post-war consumer demand, 3:22
- safety technologies, 3:23
- V8 engine, 3:22–23
- Avenger Field, 2:261–263
 - home of Women Airforce Service Pilots (WASPs) of World War II, 2:261–262
 - primary document: letters of Mary Anna Martin Wyall, WASP pilot trainee (1944), 2:262–263
- Ayers, Robert, 1:95–96, 173
- B-17 Flying Fortress, 2:263–264
- Babbitt, Isaac, 1:179–180
- Babbitt, Sarah “Tabitha” (1779–1853), 1:84, 97
- Babbitt metal, 1:179–180
- Bacon, Roger, 1:11
- Bakeland, Leo Hendrik, 2:183–184
- Baer, Ralph (1922–2014), 3:24–25
 - Brown Box (first home video console), 3:24
 - as “Father of Video Game,” 3:24
 - primary document: excerpt from paper describing plans for simple video games (1966), 3:25
- Bailey, Robert, 1:11
- Baird v. Eisenstadt*, 3:32
- Bakelite, 2:183–185
- Ball bearings and Babbitt metal, 1:179–180
- Ballard, Martha (1735–1812), 1:75, 84–85
 - on currency, 1:85–86
 - diary of, 1:85
 - and *A Midwife’s Tale* (based on Ballard’s diaries), 1:86
 - on midwifery, 1:85
 - primary document: diary excerpts describing home weaving, 1:39–40
 - on textile work, 1:39–40, 86
 - on violence against women, 1:86
- Baltimore and Ohio (B&O) Railroad, 1:310
 - competition with Chesapeake and Ohio Canal, 1:94
 - oldest U.S. railroad, 1:7, 275, 289
 - Tom Thumb* (first U.S. steam engine) created for, 1:7; 2:150, 153
- Band-Aid, 1:175; 2:175, 185
- Banjo clock, 1:87
- Banneker, Benjamin (1731–1806), 1:13–15
 - almanacs of, 1:11, 12, 13–14, 15, 177
 - primary document: letter from Thomas Jefferson expressing that blacks had talents equal to other races (1791), 1:14–15
 - primary document: frontispiece of *Pennsylvania, Delaware, Maryland and Virginia Almanack and Ephemeris* (1792), 1:15
- solar eclipses studied by, 1:13, 77
- Bar code scanner, 3:25–27
 - RFID tag as alternative to, 3:306, 307
- Baran, Paul, 3:17, 107
- Barbed wire, 2:4, 19–23, 196
 - controversial wartime use of, 2:20
 - and history of wire, 1:19
 - invention of, 2:19
 - primary document: article excerpt on Joseph F. Glidden and the barb-wire industry (1884), 2:21–23
- Bardeen, John, 3:1, 131, 140, 148
- Barnum, P. T., 1:10, 184; 2:30–31
- Barton, Clara, 1:84–85
 - Civil War nurse, 1:191
 - primary document: “The Women Who Went to the Field” (1892), 1:192–193
 - Red Cross founded by, 1:264, 306
- Bashen, Janet (1957–), 3:259
- Batteries, 2:23
 - in artificial hearts, 3:181
 - and Edison, Thomas, 2:59
 - in electric and hybrid-electric vehicles, 2:23; 3:23, 49–53, 247, 282
 - in electric doorbells, 1:123
 - and electromagnets, 1:199
 - and environmental concerns, 2:23
 - in portable electronics, 3:165, 166, 251, 286
 - rechargeable, 2:23, 38
 - in smoke detectors, 3:136
 - in transistor radios, 3:148
 - in urban electrification, 2:63
- Bayer, Friedrich, 2:18–19
- Bayer & Company, 2:18–19
- Bee smoker, 2:24–25
 - primary document: excerpt from Moses Quinby’s *Mysteries of Bee-Keeping Explained* (1853), 2:24–25
- Beecher, Catherine, 1:170
- Bell, Alexander Graham (1847–1922), 2:26–28
 - biographical details, 2:26
 - credited with first practical telephone, 2:5, 26–27, 322–325; 3:329
 - and invention of the phonograph, 2:117, 209
 - metal detector invented by, 2:97–98
 - primary document: letter to parents describing idea for the telephone (1874), 2: 27–28
- Bell, Patrick, 1:205
- Bell Telephone Laboratories (Bell Labs), 2:16, 185–186, 324
 - Advanced Mobile Phone System (AMPS) developed by, 3:218
 - Multiplexed Information and Computing Service (MULTICS), 3:314
 - transistor created at, 2:17, 324; 3:131
 - vocoder created at, 3:155

- Bellanca, Dorothy Jacobs, 2:15
- Benedictus, Edouard, 2:183
- Benerito, Ruth Rogan (1916–2013), 3:27
 permanent press fabric invented by, 3:27, 111–112
 wash-and-wear cotton fabrics developed by, 3:27
- Benham, Rhoda W., 3:13
- Benz, Karl, 2:181
- Berlin Wall, fall of, 3:164
- Berliner, Emile (1851–1929), 2:29–30
- Berners-Lee, Tim (1955–), 3:184–185
 at CERN, 3:165, 184, 208
 and creation of World Wide Web, 3:163, 165–166, 184–185
 HTML developed by, 3:165, 184, 208, 300
 HTTP developed by, 3:165, 208, 184
 URL developed by, 3:184, 208
 World Wide Web Consortium (W3C) founded by, 3:184, 209
- Berry, George Stockton, 1:205
- Bessemer, Henry, 2:1, 34–36, 89–90, 139–140, 160, 201
- Bessemer steel, 2:35–36, 89, 139–140
- Best Friend* steam engine, 1:181
- Bifocals, 1:16–17
 bifocal and progressive contact lenses, 1:17
 invention of, 1:4, 16, 26
 primary document: Benjamin Franklin’s letter describing his invention of bifocals (1725), 1:17
- Big science, 2:264–265
- Bilas (Spence), Frances, 3:1, 56
- Binney, Edwin, 2:45–46, 186–187
- Binney, Joseph, 2:46, 186
- Binney & Smith Inc., 2:46, 186–187
- Biodiesel, 3:27–38
 primary document: statement of Anne Steckel to Senate committee (2016), 3:29–31
- Birdseye, Clarence (1886–1956), 2:187–188
- Bishop, John Michael, 3:261
- Bissell, George, 2:90
- Bissell, Melville Reuben, 2:38
- Blacksmithing. *See* Iron- and silversmithing
- Blackwell, Elizabeth (1821–1910), 1:87–91
 primary document: excerpts from “Address on the Medical Education of Women” (1863), 1:89–91
- Blackwell, Emily, 1:88–91
- Blanchard, Thomas, 1:74–75, 244
- Blender, 2:188
- Blizzard Entertainment, 3:260
- Blodgett, Katherine (1898–1979), 2:188–189
- Blood transfusion, 2:173, 199, 265–266; 3:172
- Boeing, William E. (1881–1956), 2:189–190
- Boeing Company, 2:178, 189–190; 3:232, 237, 302
- Boggs, David, 3:215
- Boggs, Hale, 2:288
- Bohr, Niels, 3:80, 305
- Bomb disposal robots/units, 3:33
- Bomford, George, 1:204–205
- Borden, Gail, III, 1:173
- Boston Associates, 1:147, 161
- Boston Tunnel, 3:185–186
- Bottle-making machine, 2:190–191
- Bowditch, Nathaniel, 1:75–76, 77, 137
- Bradberry, Henrietta (1903–1979), 2:266–267
- Brandeis Brief (*Muller v. Oregon*), 2:104, 172
- Brattain, Walter, 3:1, 131, 148
- Bread slicer and wrapping machine, 2:191
- Breast pump, 1:182
- Brill, Yvonne Madalaine Claeys (1924–2013), 3:34–35
 primary document: patent for new jet propulsion technology (1974), 3:35
- Brooklyn Bridge, 2:30–31
 construction of, 2:30
 as National Historic Landmark, 2:31, 132
 primary document: photograph of promenade on Brooklyn Bridge, 2:131
 renovation (2010–2015), 2:31
- Brown, Harold Pitney, 2:62
- Brown, Josiah, Jr., 1:182–183
- Brown, Louise, 3:70
- Brown, Marie Van Brittan (1922–1999), 3:35
- Brown, Moses, 1:146–147
- Brown, Rachel Fuller, 3:5, 13–14
- Brown, William, 1:282
- Brown Box (first home video console), 3:24
- Brown Ferry Plant (nuclear plant), 2:329
- Brown Truss, 1:182–183
- Brown v. Board of Education*, 2:52
- Brownie (Kodak camera), 2:33, 57, 120, 133, 171
- Browning, John M. (1855–1926), 1:248–249
- Brownson, Orestes, 1:168, 171
- Bryant, Alice (1862–1942), 2:192
- Buchner, Joseph, 2:18
- Bulletproof vest/Kevlar, 3:36, 77
- Bullock, William, 1:174, 271
- Burglar alarm, 1:183
- Burks, Arthur, 3:55
- Burr, Theodore, 1:91–92
- Burr truss bridge, 1:91–92
- Burroughs, William S., 2:14, 114
- Burt, William Austin, 1:168, 225–226, 287
- Bush, George H. W., 3:197
- Bush, George W., 3:12, 72, 90, 239, 240, 319
- Bushnell, David (1740–c. 1824), 1:17
 primary document: engraving of American *Turtle* (1775), 1:18
 primary document: letter to Thomas Jefferson regarding experiments, 1:66–67

- Turtle* submarine created by, 1:17–18, 65, 301
 Bushnell, Nolan, 3:20–22, 119–120
- Calculators**
 Clarke Calculator (graphing calculator), 2:268
 digital logarithmic converter, 3:326
 electromechanical calculator, 3:69
 handheld calculators, 3:68, 77, 326
 and history of personal computers, 3:223–224
 microprocessors used in, 3:133
 mobile phones as, 3:219
 photovoltaic cells used in, 3:235
See also Adding machines
- Calliope (steam organ), 1:183–185
- Calutron Girls, 2:267–268
- Camera, 2:31–33
 Brownie (Kodak), 2:33, 57, 120, 133, 171
 daguerreotype, 2:31–32, 120
 digital photography, 3:167, 193–195
 first recorded movie, 2:33
 history of, 3:31–33
 in home security systems, 3:35
 photographic film, 2:120–121
 photography of Civil War, 1:256
 pinhole cameras, 2:31
 Polaroids, 3:79–80, 117–118
 in space probes, 3:75, 156, 297
 in stealth aircraft, 3:140
 in virtual reality technology, 3:324, 325
- Can opener, 3:33–34
- Canals, 1:92–95
 American canal systems, 1:6, 94
 Bridgewater Canal, 1:93
 Chesapeake and Ohio Canal, 1:94
 early canal building, 1:6
 and lamp oil discovery, 2:90
 and Industrial Revolution, 1:93
 Middlesex Canal, 1:6, 93
 oldest known American canal, 1:93
 purpose of, 1:92–93
See also Erie Canal; Panama Canal
- Cancer research, 3:261–252
 American Cancer Society (ACS), 3:262
 Cancer Genome Atlas (TCGA), 3:262
 contributions of American organizations, 3:261
 discoveries by American scientists, 3:261
 and National Cancer Act (1971), 3:261
 National Cancer Institute, 3:261–262
 Philadelphia chromosome, 3:262
- Canning factory, 1:95–96
- Cannon, Annie Jump (1863–1941), 2:192–193
- Cannon, double-barrel, 1:185–186
 primary document: excerpt from memoirs of Edward Porter Alexander on “artillery hell” at Antietam (1907), 1:186
- Carbutt, John, 2:43
- Carey (Agassiz), Elizabeth Cabot, 1:176
- Carey, Henry Charles, 1:167, 171–172
- Carnegie, Andrew (1836–1919), 2:34–35
 biographical details, 2:34, 35–36
 Carnegie Steel Company founded by, 2:34–35
 and Gilded Age “robber barons,” 2:34
 and U.S. Steel, 2:34
- Carnegie Steel Mill, 2:1, 35–37
 and competitive advantage, 2:36–37
 and cost control, 2:36
 and Panic of 1873, 2:35, 36
 primary document: correspondence of Andrew Carnegie and Henry Clay Frick regarding the Homestead Strike (1892), 2:35, 37
 purchased by Morgan, J. P., 2:35, 36–37
 and vertical integration, 2:34–36
- Carothers, Wallace (1896–1937), 2:194; 3:7
- Carpet sweeper, 2:38
- Carson, Rachel (1907–1964), 3:36–38
The Edge of the Sea, 3:37
 and public suspicion of chemical products, 3:18
The Sea Around Us, 3:6, 37
Silent Spring, 2:288–289; 3:6–7, 18, 36–38, 129–130
- Carter, Jimmy, 2:105, 228; 3:104, 113, 129, 139, 272
- Carver, George Washington (1861–1943), 2:38–39
 crop rotation innovations by, 2:39–40
 and peanut products, 2:39
 primary document: George Washington Carver addresses Congress (1921), 2:41–42
- Cash register, 2:42
- Cassini Saturn Mission, 3:127, 262–263
 discoveries of, 3:262–263
 and Jet Propulsion Laboratory (JPL), 3:75
 purpose of, 3:262
- Cayley, George, 2:165, 176
- CD and DVD, 3:186–188
- CD-ROM, 3:188–189
- Cellophane, 2:53
- Cellophane tape, 2:113, 218, 241, 253
- Celluloid, 2:42–43
- Centers for Disease Control and Prevention (CDC)
 AIDS research, 3:171, 173–174
 Jemison, Mae, at, 3:290
 polio vaccine recommendations, 3:118
- CERN (Conseil Européen pour la Recherche Nucléaire, or European Council for Nuclear Research), 3:108, 165, 184, 208
 primary document: press release, 3:109–110
- Channing, William Francis, 1:227–228
- Charpentier, Jean de, 1:176
- Charting the Gulf Stream, 1:96–97
- Child labor, 1:162, 298; 2:2, 7, 104–105
- Chlorofluorocarbons (CFCs), 3:38–39

- and aerosol spray cans, 2:176
- and Freon, 2:204–205, 220, 311; 3:38, 192
- invention of, 2:219–220; 3:38
- Christian, Charlie, 2:270–271
- Christmas tree lights, 2:194–195
- Chu, Jeffrey Chuan, 3:55
- Chuck wagon, 2:195–196
- Circular saw, 1:97–98
- Civil War medicine (1861–1865), 1:186–190
 - amputations, 1:188
 - hospitals, 1:187–188
 - long-term care, 1:188
 - primary document: report on Union casualties suffered at the Battle of Shiloh (1862), 1:188–190
 - and United States Sanitary Commission (USSC), 1:187, 306–307
 - wartime deaths, 2:186–187
 - wound treatment and surgery, 1:187–188
- Civil War nursing, 1:190–193
 - and Catholic sisters, 1:191
 - primary document: Clara Barton's poem "The Women Who Went to the Field" (1892), 1:192–193
 - race and class structure of, 1:191
- Civilian Pilot Training Program (CPTP), 2:261
- Clark, Barney, 3:180
- Clark, James H., 3:301
- Clark, William, 1:8, 123–127. *See also* Lewis and Clark Expedition
- Clarke, Edith (1883–1959), 2:268
- Clarke, William Edward, 1:178
- Clarke calculator, 2:268
- Clarke School for the Deaf, 2:26
- Climate change, 3:39–41
 - and carbon capture and storage (CCS), 3:40
 - causes of, 3:39
 - and dams, 2:213
 - disagreements and controversy, 3:39
 - and Freon, 2:311
 - and *An Inconvenient Truth* (documentary), 3:39
 - and Kyoto Treaty, 3:40
 - and Paris Agreement, 3:41
 - and solar radiation management, 3:40
 - and urban electrification, 2:65
- Clinton, Bill, 3:227
 - and International Space Station, 3:284
 - and Kyoto Treaty, 3:40
 - military reduced by, 3:90
- Clinton, Hillary, 3:323
- Clipper ship, 1:194–196
 - Baltimore clippers, 1:194
 - packet ships, 1:194
 - primary document: journal excerpts of Alexander Van Valen describing journey to California via clipper ship (1849), 1:196
 - Rainbow* (considered first true clipper), 1:194
- Clothespin, 1:196–197
- CO₂ welding, 3:41
- Coal-mining technologies, 1:197–198
 - and damp (gas pockets), 1:198
 - early coal mining, 1:198
 - and labor unions, 1:198
 - safety of, 1:198
 - stripmining, 1:197
 - surface mining, 1:197
 - underground mining, 1:197–198
- Coca-Cola, 2:43–44
- Cochran, Jacqueline, 2:263, 331–332
 - and formation of Women's Airforce Service Pilots (WASPs), 2:331–332
 - Women's Flying Training Detachment (WFTD) director, 2:261, 332
- Cochran, Josephine, 2:4, 48–49
- Coffee percolator, 1:98–99
- Coil magnet/electromagnet, 1:199
- Cold War (1946–1979), 3:1–8
 - advances in biological science and medicine, 3:4
 - dawn of computer science, 3:1
 - definition of, 3:1
 - environmental activism, 3:6–7
 - global communications and Internet, 3:2–3
 - nuclear arms and nuclear power, 3:5–6
 - rapid technological change, 3:1
 - Space Race, 3:3–4
 - widespread use of synthetic materials, 3:7
- Colden, Jane (1724–1766), 1:19–20, 45
- Colgate, William (1783–1857), 1:200
- Collier, Ralph, 1:222
- Colton, Gardner Quincy, 1:178
- Colonial America and Enlightenment society, 1:1–8
 - as "Age of Reason," 1:1
 - cotton industry, 1:5–6
 - economics of colonial settlements, 1:2–3
 - and England's Iron Act (1750), 1:3
 - harnessing electricity, 1:1
 - indigenous people's experience, 1:2
 - and Industrial Revolution, 1:4–5
 - Jamestown colony, 1:2, 38
 - and mercantile system, 1:3, 5, 60–61, 138
 - putting-out production replaced by factory system, 1:4, 5
 - study of natural sciences, 1:3–4
 - transportation advances, 1:1
- Colored Female Free Produce Society, 1:201–202
- Colt, Samuel (1814–1862), 1:202–203
 - Colt Patent Fire-Arms Manufacturing Company, 1:202
- Colt revolver, 1:203–204
- Columbiad Cannon, 1:204–205
- Colvin, Margaret, 2:4, 134
- Combine harvester, 1:205–207

- Commodore 64, 3:42, 224
 Compact iron stove, 1:207–208
 Comptometer, 2:113–114. *See also* Adding machines
 Computer/information technology, 3:189–191. *See also*
 Apple; Apple II; Commodore 64; IBM personal
 computer; Personal computer
 Comsat/Intelsat, 3:42–43
 and Communications Satellite Act (1962), 3:2, 42
 creation of COMSAT Corporation, 3:2
 Intelsat I (first operational satellite), 3:42
 Comstock Law (1873), 3:32
 Conestoga wagon, 1:208–211
 primary document: excerpt from John G. Abbott's
 recollections of traveling to California by wagon train
 (1852), 1:210–211
 Constitution. *See* United States Constitution
 Constitutional Convention (1776), 1:53
 Constitutional Convention (1787), 1:26, 112, 136
 Cook, Tim, 3:179
 Coolidge, Calvin, 2:174, 237
 Coolidge, William D., 2:199–200
 Cooper, Gordon, 3:88
 Cooper, Leon Neil, 3:140–141
 Cooper, Martin, 3:218
 Cooper, Peter
 first steam-powered locomotive (*Tom Thumb*) created by,
 1:7, 150, 289; 2:150
 grandfather to Hewitt, Peter C., 2:210
 primary document: John Latrobe's description of *Tom*
 Thumb, 2:150–152
 wrought iron beams pioneered by, 2:139
 Cooper pairs, 3:141
 Corn sheller, 1:211
 Corps of Discovery. *See* Lewis and Clark Expedition
 Corset, 1:211–213
 Coston, Martha (1826–1904), 1:213
 Cotton candy machine, 2:45
 Cotton gin, 1:99–101, 119
 and demand for cotton, 1:101
 Greene, Catharine Littlefield, as coinventor of, 1:5, 116,
 117, 164–165
 influence and legacy of, 1:5, 74, 82, 86, 99–100
 invention of, 1:5, 99, 164–165
 and spinning wheel, 1:60, 61
 and Waltham-Lowell textile system, 1:161
 Cotton sewing thread, 1:101
 Cowboy hat (Stetson), 1:213–214
 Crane, Clarence, 2:217
 Cray, Seymour (1925–1996), 3:191–192
 Crayons, 2:45–46
 Crick, Francis, 3:5, 202
 Crocker, Charles, 1:275, 290
 Crosby, Caresse. *See* Jacob, Mary Phelps
 Crosley Motors, 2:182
 Crump, Scott, 3:316
 Crumpler, Rebecca (1831–1895), 1:214–215
 Crystal Palace Exhibition. *See* Great Exhibition of 1851
 (London)
 Curanderas, 3:43–45
 Curling iron, 2:47
 Curtiss-Wright Aeronautical Engineering Cadettes,
 2:269–270
 Cuvier, Georges, 1:176
 Cylinder pin tumbler lock, 1:216
 Czarnecki, Kazimierz, 3:73
 D rations, 2:270, 300
 da Vinci, Leonardo, 2:143
 and flying machines, 2:176, 177
 gas engine prototype, 2:247
 and pedometer, 1:122
 pinhole camera used by, 2:31
 and underwater sound waves, 2:318
 da Vinci Surgical System, 3:229, 230–232, 250
 Dabney, Ted, 3:20–22, 119–120
 Daguerre, Louis, 2:31–32, 130
 Dahlgren gun, 1:216–217
 Dark matter science, 3:45–47
 Darken, Joanne, 3:19
 Dart, Joseph, 1:233–234
 Darwin, Charles
 American Philosophical Society member, 1:9
 evolution theory opposed by Agassiz, Louis,
 1:175, 176
 Gosling, James, on Darwinism, computers, and human
 evolution, 3:289
 and Haeckel, Ernst, 2:129
 Hawking, Stephen, compared to, 3:277
 Rush, Benjamin, on, 1:145
 on “selective breeding,” 3:202
 Davidson, Arthur, 2:221–222
 Davis, Donald, 3:107
 Davis, Jack, 3:35
 Davis, Jan, 3:291
 Davy, Humphry
 arc lamp of, 1:198
 nitrous oxide experiments of, 1:246, 247
 and short electric arc, 1:116, 198
 Daylight Saving Time, 1:20
 DDT (dichlorodiphenyltrichloroethane), 2:301; 3:6, 18, 36,
 38, 130
 de Forest, Lee (1873–1961), 2:196–197
 de la Peña, Carolyn, 2:136; 3:19
 de Smedt, Edward J., 2:17–18
 Deductive reasoning, 1:1, 3, 7
 Deere, John (1804–1886) and Deere and Company, 1:159,
 205, 217–220
 polished steel plow invented by, 1:171, 217–218, 269

- Defense Advanced Research Projects Agency (DARPA), 3:2–3, 16, 208. *See also* ARPANET
- Dell, Michael “Saul” (1965–), 3:192–193
- Demikhov, Vladimir, 3:180
- Demorest, Ellen Curtis, 1:286
- Denison, Lester E., 1:211
- Denny, James, 3:19
- Denny, Reginald, 3:48
- Dental chair, 1:219
- Dental floss, 1:102–103
- Detachable collar, 1:219–220
- Dexter, Henrietta F., 3:13
- Dickelman, Elizabeth (dates unknown), 2:197
- Dickerson, Mary Cynthia (1866–1923), 2:197–198
- Diesel, Rudolph, 3:28
- Diffraction grating, 1:103
- Digital photography, 3:193–195
primary document: excerpt from patent for Kodak’s digital camera (1978), 3:195
- Diner (horse-drawn), 2:47–48
- Dishwashing machine, 2:48–49
- Dix, Dorothea (1802–1887), 1:220–221, 308
activist for mentally ill, 1:220–221
Civil War superintendent of army nurses, 1:187, 191, 221, 264
and U.S. Sanitary Commission (USSC), 1:306
- DNA (deoxyribonucleic acid), 3:4–5, 93, 109, 153, 196
gene patenting, 3:270–271
genetic engineering, 3:201–205
genetically modified foods, 3:271–273
Human Genome Project, 3:279–280
- Dolby Laboratories, 3:47
- Dow Chemical Company, 2:49–50
- Drake equation, 3:264
- Dred Scott v. Sandford*, 1:172
- Drew, Charles (1904–1950), 2:198–199
- Drones, 3:48–49
and Amazon package delivery, 3:258
and artificial intelligence, 3:183
drone warfare, 2:301–302; 3:48
electroexpulsive technology used in, 3:255
history of, 3:48
“Lightning Bugs,” 3:49
as natural progression of helicopter technology, 2:277
Predator missiles, 3:48
Quail decoy drone, 3:140
and stealth technology, 3:140
in World War I, 3:48
World War II German drones, 2:301–302
- Du Mont, Allen B., 1:78
- du Pont, Éleuthère Irénée, 1:77
- du Pont, Pierre (1870–1954), 2:50–52
- Duct tape, 1:175; 2:256. *See also* Adhesive tape
- Ductile tungsten, 2:199–200
- Dudley, Benjamin, 1:246–247
- Dudley, Homer, 3:155
- DuPont Company, 1:77; 2:52–54
- Duprey, Ana Roqué de (1853–1933), 2:54
- Duryea, Charles (1861–1938) and Frank (1869–1967), 2:54–55
- Dust Bowl
and Lend-Lease Program, 2:294
photographs by Lange, Dorothea, of, 2:292–293
overfarming as cause of, 1:207
- Dustpan, 1:221–222
- Earth Resources Technology Satellite (ERTS-1), 3:2
- Ebers Papyrus (Egyptian medical scroll of herbal knowledge), 2:18
- e-book and e-reader, 3:264–266
Kindle, 3:251, 258, 265, 312
- e-Sports, 3:267–268
- Earl, Harley, 2:183
- Earmuffs, 2:55
- Eastman, George (1854–1932), 2:56
- Eastman Kodak Company, 2:56–57
- Eckert, John Presper, 3:55, 150–151
- Eckert-Mauchly Computer Corporation, 3:65, 69
- Edison, Thomas (1847–1931), 2:5, 40, 43, 57–59, 143, 194–195, 324
biographical details, 2:57–58
direct current system, 2:107, 147–148
and Ford, Henry, 2:59, 203
Kinematoscope, 2:6, 91, 103
lightbulb patented by, 2:47, 58
and motion pictures, 2:243–244
phonograph invented by, 2:115–118, 208–210
quadruplex telegraph invented by, 2:26, 124–125
- Edison effect, 2:196
- Edison Electric Light Company, 2:5, 61, 194
- Edison General Electric Company, 2:74
- Edwards, Robert, 3:70
- Eggbeater, 1:222
- Eichengrün, Arthur, 2:19
- Einstein, Albert (1879–1955), 2:199–201, 224, 260, 271–272, 304, 317
biographical details, 2:199–200
on dangers of nuclear weapons, 3:201, 111
photoelectric effect defined by, 3:235
and quantum science, 3:304–305
stimulated emissions theory proposed by, 3:80
- Eisenhower, Dwight D.
Atoms for Peace program, 3:6, 128
election of 1952, 3:151
and Federal-Aid Highway Act (1956), 3:23
and military-industrial complex, 3:88–90
NASA established by, 3:3, 94, 137

- and oil quotas, 3:112
- primary document: letter to Glennan, Keith, retiring administrator of NASA, 3:98
- and Shippingport Atomic Power Station, 3:128–129
- Electric car, 3:49–53, 247, 281
 - primary document: article from the energy.gov web site (2014), 3:50–53
- Electric doorbell, 1:223–224
- Electric guitar, 2:270–271
- Electric iron, 2:59–60
- Electric lightbulb, 2:60–61
- Electric stove, 1:223
- Electric street railway, 1:223–224
- Electrical tape, 1:175. *See also* Adhesive tape
- Electricity, war of the currents, 2:61–63
- Electrification, urban, 2:63–65
- Electroexpulsive technology, 3:254–255
- Electromagnetic induction, 1:7, 168, 237; 2:10–11, 323. *See also* AC induction motor
- Electronic Numerical Integrator and Computer. *See* ENIAC and the “ENIAC Girls”
- Elevator safety brake, 1:224–225
- Elion, Gertrude (1918–1999), 3:195–197
- Emerson, Ralph Waldo, 1:168, 171
- Empire State Building, 2:201–202
- Enders, John Franklin (1897–1985), 3:4, 54
- Engelbart, Douglas (1925–2013), 3:3, 55
- ENIAC and the “ENIAC Girls,” 3:1, 55–56
 - designers, 3:55, 151
 - first electronic general-purpose computer, 3:55
 - programmers (ENIAC Girls), 3:56
 - purpose of, 3:55, 189
- Enlightenment
 - and consequences of change, 1:7–8
 - and deductive reasoning, 1:1, 3, 7
 - impact of, 1:1
 - and inoculation, 3:151–152
 - population redistribution, 1:8
 - Tesla, Nikola, on Niagara Falls Power Plant as testament to, 2:110
- See also* Colonial America and Enlightenment society
- Equatorial sextant, 1:168, 225–226, 287
- Erie Canal, 1:104–107, 245
 - construction of, 1:6, 105
 - importance and legacy of, 1:6, 76, 78, 83, 94, 105, 233
 - primary document: letter of Robert Fulton to George Washington urging construction of canals (1797), 1:106–107
 - and steam railroad construction, 1:7, 105, 293
- Escalator, 2:65–67
- Ethernet, 3:132, 190, 214–215
- Evans, Oliver (1755–1819), 1:79–81, 107–109
 - biographical details, 1:79, 107
- first amphibious steam vehicle (*Oruktor Amphibolos*) built by, 1:79–80, 107, 118
- high-pressure steam engine developed by, 1:117–118
- ice-making machine designed by, 1:161, 268
- influence of, 1:73–74, 76–77, 107–108, 117–118
- and patent conflict with Jefferson, Thomas, 1:108–109, 136
- Mars Iron Works founded by, 1:118
- primary document: image of amphibious steam vehicle (1834), 1:81
- primary document: letters to Thomas Jefferson (1804, 1808), 1:108–109
- steam-powered flour mill invented by, 1:73–74, 107, 107–108, 234
- The Young Millwright and Miller’s Guide*, 1:73, 107
- Explorer (browser). *See* Internet Explorer
- Explorer I, 3:3, 74, 92, 93, 95, 121
- Extension arm (long arm), 1:21
- Extinction, species, 1:47, 175, 176; 3:250
- Facebook, 3:268–270
- Fahlberg, Constantin, 2:135–136; 3:18
- Fairbanks, Erastus, 1:168; 2:268–269
- Fairbanks, Thaddeus, 1:168, 268–269, 291
- Falconer, Etta, 3:20
- Faraday, Michael, 1:7, 168, 237; 2:10, 323
- Farber, Sidney, 3:261
- Federal-Aid Highway Act (1956), 2:287–290
 - primary document: excerpt from the Federal-Aid Highway Act (1956), 2:289–290
- Fender, Leo, 2:271
- Fermi, Enrico (1901–1954), 2:260, 271–272, 283, 296, 331
- Ferraris, Galileo, 2:10
- Ferris wheel, 2:66–68
 - primary document: telegrams between Luther Rice and George Ferris on successful test of the Ferris wheel (1893), 2:68
- Feynman, Richard P., 2:260, 317; 3:93
- Field, Cyrus West (1819–1892), 1:226–227; 2:5
- Finely, Susan, 3:121
- Fire alarm call box, 1:227–228
- Fire hydrant, 1:109–111
 - primary document: account of the Detroit Fire (1805), 1:110–111
- Fire Safety, 1:21–22
- Fitch, John (1743–1798), 1:76, 111–112
 - biographical details, 1:111
 - first successful steam-powered boat developed by, 1:111–112, 115, 151
 - monopoly granted to, 1:111–112, 136, 293
- Fitzroy, Nancy DeLoye, 1:78
- Flatboat, 1:112–114
- Flexible catheter, 1:22–23

- Floating dry dock (1849), 1:228–230
 primary document: excerpt from Abraham Lincoln's patent application for the floating dry dock (1849), 1:229–230
- Floppy disk, 3:197–198
- FM radio, 2:272–273
- Folding cabinet bed, 2:68–70
 primary document: patent for folding cabinet bed (1885), 2:69–70
- Folger, Timothy, 1:96–97
- Folsom, Joseph Libbey, 1:172
- Food and Drug Administration (FDA), 3:172
 and AIDS research, 3:172, 239
 and artificial sweeteners, 2:137; 3:18–19
 and birth control, 3:32, 307
 on cosmetic surgery, 3:249
 creation of, 2:172
 first female lab chief, 2:232
 and genetically modified foods, 3:272
 primary document: letter on regulation of robotic surgery (2013), 3:230–232
 and robotic surgery, 3:229, 230, 250
 and toothpaste categorization, 1:300
- Food preservation, 2:70–71
- Food production, Native American, 1:23–25
- Ford, Henry (1863–1947), 2:36, 40, 202–204
 and assembly line, 2:170, 179–181
 biographical details, 2:202–203
 and Edison, Thomas, 2:59, 203
 “Fordism,” 2:204
 Model A, 2:181, 203–204
 Model T, 2:170, 180, 182, 203–204
- Fortran, 3:56–57, 69, 121, 155
- Fossey, Dian (1932–1985), 3:198–199
- Fountain pen, 2:71–72
- Franklin, Benjamin (1706–1790), 1:4, 25–27
 American Philosophical Society created by, 1:4, 71–72
 electricity experiments, 1:4
 glass armonica invented by, 1:4, 31, 32
 primary document: letter describing experiments with electricity (c. 1750), 1:26–27
- Franklin, James, 1:11, 25
- Franklin stove, 1:27–31
 primary document: Excerpt from *An Account of the New Invented Pennsylvanian Fire-Places* (1744), 1:28–31
- Frasch process, 2:72–72
- Freeze-dried food, 2:273
- Freireich, Emil Jay, 3:261
- French and Indian War (1754–1763), 1:3, 35, 208
- Freon, 2:204–205, 215, 220, 311; 3:38, 192
- Frick, Henry Clay, 2:35
 primary document: correspondence with Andrew Carnegie regarding Homestead Strike (1892), 2:37
- Fugitive Slave Act (“Compromise of 1850”), 1:172
- Fuller, Richard Buckminster (1895–1983), 3:57–58
 primary document: drawing of R. Buckminster Fuller's Geodesic Dome (c. 1933), 3:58
- Fulton, Robert (1765–1815), 1:114–115
- Gaffer tape, 1:175. *See also* Adhesive tape
- Gagarin, Yuri, 3:4, 237
- Gallo, Robert, 3:172, 175
- Galvin, Joseph, 2:205
- Galvin, Paul Vincent (1895–1959), 2:205–206
 biographical details, 2:205
 mass production process of automotive radios created by, 2:205–206
 Motorola cofounded by, 2:182
 and Motorola 5T71 radio, 2:205–206
- Garbage disposal, 2:273–274
- Gas mask, 2:274
- Gas transmission, 2:73–74
- Gas tungsten arc welding, 1:115–116
- Gas well, 1:230
- Gates, Bill (1955–), 3:163, 199–201, 244
 on artificial intelligence, 3:183, 191
 Bill & Melinda Gates Foundation, 3:212, 199, 201, 270
 cofounder of Microsoft, 3:190, 199–201, 217, 218
 and Jobs, Steve, 3:211, 212
- Gatling, Richard, 1:174, 247–248
- Gene patenting, 3:270–271
- General Electric, 2:74–75
- General Motors (GM), 2:206–207
- Genetic engineering, 3:201–204
- Genetically modified foods, 3:271–273
- Geographic Information Systems (GIS), 3:164
- Gibbs, Mifflin Wistar, 1:173
- Gilbreth, Lillian (1878–1972), 2:208
- Gilleland, John, 1:185
- Gilpin, Thomas, 1:266
- Glass harmonica (Armonica), 1:30–32
 primary document: excerpt of Benjamin Franklin's letter describing the glass harmonica (1762), 1:32
- Glenn, John
 first manned satellite (Friendship 7) piloted by, 3:95
 Mercury 7 crew member, 3:88, 95
 oldest human to fly in space, 3:238
- Glenn, William, 3:180
- Glennan, Keith, 3:98, 137
- Glidden, Carlos, 2:155
- Glidden, Joseph F., 2:19–23
- Gliders, 2:165, 176–177
- Global Positioning System (GPS), 3:59–60
- Glover, Elizabeth (d. 1643), 1:32–33
- Goddard, Robert H., 2:312
- Godfrey, Thomas (1704–1749), 1:33–34
- Goeppert-Mayer, Maria (1906–1972), 3:60–61
- Gold-mining technologies, 1:231–232

- Golden Gate Bridge, 2:274–276
 primary document: letter of Charles Ellis to the *San Francisco Chronicle* (1930), 2:275–276
- Goldmann, Felix, 2:19
- Goldsmiths, 1:36, 180, 267. *See also* Iron- and silversmithing
- Goode, Sarah Elizabeth, 2:4, 68–70
- Goodhue, Lyle, 2:176
- Goodnight, Charles, 2:195–196
- Goodrich, B. F. (1841–1888), 2:75–76
- Goodyear, Charles (1800–1860), 1:232–233, 307–308
- Goodyear, Charles, Jr. (1833–1896), 2:76
- Google, 3:274–275
- Google Earth, 3:275–276
- Gorbachev, Mikhail, 3:164
- Gore, Al, 3:17, 39
- Gorelick (Ratley), Sarah, 3:88
- Gosling, James (1955–), 3:204
- Graham, Bette (1924–1980), 3:61–62
- Graham, Evarts Ambrose, 3:261
- Graham, Sylvester, 1:236
- Grain elevator, 1:233–234
- Gramophone/Victrola, 2:208–210
- Grandin, Temple (1947–), 3:276–277
- Gray, Elisha, 2:26–28, 323–324
- Gray, Mary, 3:20–21
- Great Depression and World War II (1930–1945), 2:251–257
 adhesive tape’s popularity during, 2:241
 and automobile industry, 2:181–183, 204, 206, 207
 contribution to decline in railroad ridership, 1:290–291
 debut of Sunbeam’s Mixmaster during, 1:222
 effect on farm equipment manufacturing, 1:206
 and end of Golden Age of amusement parks, 2:134
 and end of products and companies, 1:208; 2:210
 entertainment during, 2:255
 and food, 2:136, 145
 and Hoover, Herbert, 2:251
 and Hoover Dam, 2:251, 252, 277–283
 and labor response by Kellogg, William Keith, 2:88
 and radio, 2:237
 and Roosevelt, Franklin D., 2:251–254
 scientific advances during, 2:253–253
 and Tennessee Valley Authority (TVA), 2:251–252
 See also Dust Bowl; New Deal; Roosevelt, Franklin D.
- Great Exhibition of 1851 (London), 1:238; 2:162
 Colt Revolver at, 1:204
 equatorial sextant (solar compass) at, 1:225
 McCormick Reaper awarded grand prize at, 1:253
 omnibuses at, 1:265
 Otis elevator at, 2:139
 telegraph at, 1:310
- Greene, Catharine Littlefield (1755–1814), 1:116–117
- Grey, Henry, 2:140
- Gridiron for cooking, 1:234
- Griswold v. Connecticut*, 3:32
- Groves, Leslie R., 2:260
- Gumball machine, 2:210
- Gunsmiths, 1:174, 202, 203, 281, 243–244; 2:80. *See also* Iron- and silversmithing
- Gutenberg, Johann, 1:270–271
- Hadaway, William, 1:223
- Hall, David D., 1:1
- Hall, John, 1:74–75, 244, 281
- Halley, Edmund, 1:33, 96
- Hallidie, Andrew Smith (1836–1900), 2:76–77
- Halsted, William Stewart, 3:261
- Hamilton, Alexander, 1:8, 167; 3:128
 Report on Manufactures, 1:72, 138–139, 284
- Hamilton, Margaret (1936–), 3:62–63
- Hammes, John, 2:273
- Hammond, William, 1:187
- Han, Otto, 2:260
- Hanchett, Milton Waldo, 1:219
- Hand-cranked ice cream maker, 1:234–235
- Hanson, Alvah, 1:206
- Harley, Arthur, 2:221–222
- Harley-Davidson Motor Company, 2:221–222
- Harper, Frances Ellen Watkins, 1:201
- Hart, William, 1:230
- Harvard Computers, 2:77–79
 primary document: undated photo of Harvard Computers, 2:79
- Haslim, Leonard A., 3:254
- Hawking, Stephen (1942–2018), 3:277–278
- Hawkins, John Isaac, 1:16
- Haynes, Elwood (1857–1925), 2:79–80
- Haynes, Martha Euphemia Lofton (1890–1980), 3:63–64
- Hazen, Elizabeth, 3:5, 13–14
- Health reform, 1:235–237
- Heisenberg, Werner, 3:80, 305
- Helicopter, 2:276–277
- Helin, Eleanor Francis, 3:121
 primary document: press release naming Helin to WITI Hall of Fame, 3:122–123
- Henry, Benjamin Tyler, 1:174, 281
- Henry, Joseph (1797–1878), 1:78, 237–238
 biographical details, 1:237
 electric doorbell invented by, 1:199, 223
 and electromagnetic induction, 1:7, 237
 electromagnets designed by, 1:199, 237, 310
 electromechanical relay invented by, 1:169, 280
 and Morse, Samuel, 1:237, 261
 and National Academy of the Sciences, 1:238
 and Smithsonian Institution, 1:7, 237–238
 and U.S. Light-House Board, 1:237–238
- Henry rifle, 1:174
- Hershey, 2:173, 270, 300
- Hertz, Roy, 3:261

- Hewitt, Peter C. (1861–1921), 2:210–212
- Heydenfeldt, Solomon, 1:172–173
- Heyl, Henry (1842–1919), 2:80–81
- Hicks, Elias, 1:201
- High-pressure steam engine, 1:117–118
- Hilde, Libra R., 1:191
- Hillman, Bessie Abramowitz, 2:14–15
- Hillman, Sidney, 2:15
- Hinckley, Robert C., 1:178
- HIV. *See* AIDS research
- Hoe, Richard, 1:169, 271
- Hoffmann, Felix, 2:18–19
- Holland, James Frederick, 3:261
- Hoop skirt, 1:238–239
- Hoosier cabinet, 2:212
- Hoover, Erna, 3:143
- Hoover, Herbert, 2:88, 251
- Hoover Dam, 2:213, 277–283; 3:128
 environmental effects of, 2:213
 and Great Depression, 2:251, 252, 277–283
 primary document: Franklin D. Roosevelt’s dedication
 speech, 2:280–283
- Hopkins, Mark, 1:290
- Hopper, Grace (1906–1992), 3:1, 65–66
- Horse-drawn streetcar, 1:239–240
 primary document: image of horse-drawn streetcar (c. 1920),
 1:240
- Hospital Transport Service, Women’s Department, 1:240–241
- Hot air balloon, 2:176–177
- House, Royal E., 1:169, 272
- Howe, Elias (1819–1867), 1:241–242
 Automatic, Continuous Clothing Closure patent, 1:311
 biographical details, 1:241–242
 mechanized sewing machine patent, 1:5–6, 171, 242, 285,
 311
 patent battle with Singer, Isaac, 1:6, 285
 transverse shuttle invented by, 1:171, 303
- Howe, Richard, 1:65
- Howe, William, 1:242–243
- Howe truss, 1:242–243
- Hubble Space Telescope, 2:264; 3:278–279
- Hudson, Thomas, 1:54–55
- Hudson Canal Company, 1:245, 289
- Hudson Motor Car Company, 2:182
- Hudson River Rubber Company, 2:75
- Huggins, Charles Brenton, 3:261
- Hughes, Chris, 3:268
- Hughes, Howard, 3:42
- Hughes Aircraft, 3:2, 42
- Hull, Chuck, 3:316
- Hülsmeier, Christian, 2:309–310
- Human Genome Project, 3:279–380
- Human immunodeficiency virus (HIV). *See* AIDS research
- Humboldt, Alexander, von, 1:9, 46, 176
- Hungerford, David, 3:261
- Hunt, Walter
 breech-loading rifle designed by, 1:174, 284
 lockstitch sewing machine invented by, 1:170–171, 284,
 285
 Rocket Ball ammunition patented by, 1:281
 safety pin patented by, 1:285
- Hunter, John, 1:57
- Huntington, Collis, 1:275, 276, 290
- Huskey, Harry, 3:55
- Hyatt, Isaiah, 2:42–43
- Hyatt, John Wesley, 2:42–43
- Hybrid vehicles, 3:281–283
- Hydraulic fracturing (“fracking”), 3:66–67
- Hydroelectric power, 2:212–214
- Hydrogen bomb, 2:283
- Hydrogen energy, 3:67–68
- Hydroponics, 2:284–285
- Hypertext, 3:283
- Hypertext Markup Language (HTML), 3:165, 184, 208, 283,
 300
- Hypertext Transfer Protocol (HTTP), 3:165, 184, 208
- IBM 360 Computer, 3:17, 68–69
- IBM personal computer, 3:205–206
- Ice cream soda, 2:81–82
- In vitro fertilization (IVF), 3:70
- Indigo
 dyed jeans, 2:84–85
 experimentation of Lucas, Eliza, 1:3, 40, 41
 and slave labor, 1:71, 72
- Induction. *See* Electromagnetic induction
- Industrialism, Reconstruction, and the Gilded Age (1866–1900),
 2:1–7
 communication innovation, 2:7
 consumerism, 2:5–7
 defining issues, 2:1
 female entrepreneurship, 2:4–5
 industrialization of leisure, 2:5
 newspaper muckrakers, 2:2, 7, 172
 record number of patents, 2:1
 Reconstruction, 2:2–3
 public health and the modern city, 2:6–7
 Transcontinental Railroad, 2:3–4
- Infant formula, 3:206–207
- Inman, George (1895–1972), 2:82–83
- Insulin pump, 3:207–208
- Integrated circuit, 3:70–71, 76–77, 99–102, 132, 190, 192, 216
- Intel Corporation, 3:71–72
- Interchangeable gun parts, 1:243–244
- Interchangeable parts, 1:118–119
- Intercontinental ballistic missiles (ICBMs), 3:12, 239

- Minuteman I, 3:2
- R-7, 3:3
- Internal combustion engine, 1:119–121
 - development of, 2:119–121, 131–132, 181, 203
 - in hybrid vehicles, 3:281
 - steam engine replaced by, 1:149, 150
 - in submarines, 2:319
- International Ladies' Garment Workers' Union (ILGWU), 2:285–287
 - primary document: "The Uprising of the 20,000," 2:286–287
- International Space Station, 3:97, 105, 126–127, 166, 237–238, 283–285
- Internet, 3:208–209
 - ARPANET as forerunner to, 3:2–3, 16, 164, 190, 208, 300, 329
 - and Berners-Lee, Tim, 3:163, 165–166, 184–185
 - and net neutrality, 3:209
- Internet Explorer, 3:166, 190, 217, 301
- Internet Protocol (IP)
 - development of, 3:300
 - and early Internet, 3:17, 208
 - and 4G, 3:219
 - and packet switching, 3:17, 107
 - TCP/IP, 3:3, 107, 208, 300
- Interstate Highway System, 2:287–290
 - primary document: excerpt from the Federal-Aid Highway Act (1956), 2:289–290
- Intraocular contact lens, 3:285–286
- Inverted microscope, 1:244–245
- iPod, 3:286–287. *See also* Apple
- Iron ship with revolving turret, 2:83
- Iron- and silversmithing, 1:34–35
 - apprenticeships, 1:217
 - blacksmithing, 1:34–35
 - blacksmiths, 1:111, 163, 171, 209, 211, 217, 269; 2:156; 3:50
 - and cast-iron "Saugus pot," 1:54
 - in Colonial America, 1:3
 - and Conestoga tires, 1:209
 - and Deere, John, 1:171, 217, 269
 - definition of, 1:34
 - and Fitch, John, 1:111
 - and flexible catheter, 1:22
 - gunsmiths, 1:174, 202, 203, 281, 243–244; 2:80
 - and Michaux, Pierre, 2:156
 - and polished steel plow, 1:269
 - silversmiths, 1:22, 71, 111
 - and three-piece iron plow, 1:160
 - women as, 2:313–314
- Ironing board, 2:83
- Jackson, Andrew
 - and French and Indian Wars, 1:210
- Jacksonian democracy, 1:167
 - and Kentucky Rife in War of 1812, 1:35–36
 - and National Road, 1:134
 - and Panama Canal, 2:226
 - on Slater, Samuel, 1:147–148
 - urbanization and industrialization under, 1:235
- Jackson, Charles Thomas, 1:178
- Jackson, Janet, 3:323
- Jackson, Mary Winston (1921–2005), 3:72–74
 - biographical details, 3:72–73
 - career featured in *Hidden Figures* (film), 3:74
 - NASA's first black female engineer, 3:72, 73, 155
 - at West End Computers, 3:155
- Jackson, Michael, 2:118
- Jackson, Sandra Willett, 2:105
- Jackson, Thomas J. (Stonewall), 1:257
- Jackson, Thomas Penfield, 3:200, 301
- Jackson, Wes, 3:240
- Jacob, Mary Phelps (1891–1970), 2:214–215
- Janeway, Henry, 1:179
- Jarvik, Robert, 3:180
- Jarvik-7 artificial heart, 3:180
- Java, 3:287–290
 - primary document: interview with James Gosling, creator of Java (2001), 3:288–290
- Jeans, 2:84–86
- Jefferson, Thomas (1743–1826), 1:121–123
 - and agrarian versus manufacturing debate, 1:138, 139
 - American Philosophical Society member and president, 1:4, 8–9, 158
 - Dunbar and Freeman expedition ordered by, 1:4
 - federal banking system opposed by, 1:139
 - lap desk invented by, 1:4, 121, 122
 - Lewis and Clark Expedition ordered by, 1:4, 8, 45, 77, 123–125
 - moldboard plow invented by, 1:4, 122
 - Monticello, 1:122–123, 124, 141, 157–158, 162
 - and natural history, 1:4
 - and patent law, 1:135–137
 - primary document: excerpts from notes on wheel cipher, 1:163
 - Rush, Benjamin, eulogized by, 1:144
 - swivel chair invented by, 1:4, 157–158
 - wheel cipher invented by, 1:4, 162–163
- Jemison, Mae (1956–), 3:290–291
- Jencks, Joseph, 1:45, 54–55, 71, 76, 101, 136
- Jennings (Bartik), Betty Jean, 3:1, 56
- Jennings, Lewis, 1:281
- Jennings, Thomas L., 1:77
- Jervis, John B. (1795–1885), 1:245
- Jet Propulsion Laboratory (JPL), 3:74–75
 - Rocket Girls of JPL, 3:121–123
- Jobs, Steve (1955–2011), 3:80, 158, 163, 177–179, 209–213, 223, 244

- at Atari, 3:209, 244
- biographical details, 3:209–210
- and development of the iPhone, 3:212, 311–312
- and development of the iPod, 3:286
- NeXT, 3:178, 210, 213
- Pixar, 3:209, 210
- Jockstrap, 2:86
- Johnson, Andrew, 1:309
- Johnson, Clarence Kelly, 3:139–140
- Johnson, Edward H., 2:194–195
- Johnson, Eldridge, 2:29
- Johnson, Herbert, 1:222
- Johnson, Katherine Goble (1918–), 3:75–76, 155
- Johnson, “Lady Bird,” 2:289
- Johnson, Lyndon B., 2:105, 304
 - and Sentinel missile defense system, 3:239
 - War on Poverty, 3:106
- Johnson, Nancy M., 1:235
- Johnson, Willis, 1:222
- Johnson & Johnson, 1:175; 2:185; 3:196, 255
- Johnson Space Center, 3:105
- Joint United Nations Programme on AIDS (UNAIDS), 3:172–173
- Jones, Amanda T. (1835–1914), 2:86–87
 - primary document: “The Soldier’s Mother” by Amanda T. Jones (1867), 2:87
- Joystick/flight simulator, 3:291
- Kahn, Albert, 2:180
- Kahn, Robert, 3:3
- Kaposi’s sarcoma, 3:171, 173. *See also* AIDS research
- Kare, Susan (1954–), 3:213
- Keen, William W., 1:188
- Kellogg, William Keith (1860–1951), 2:88–89
- Kelly, Michael, 2:4
- Kelly, William (1811–1888), 2:89–90
- Kennedy, John F.
 - and Apollo Project, 3:14, 95
 - and Communications Satellite Act (1962), 3:42
 - and Operation Ranch Hand (Vietnam War herbicidal warfare program), 3:9
 - and Partial Test Ban Treaty (1963), 3:111
 - testing touch-tone phone at Seattle World’s Fair, 3:145
 - “Urgent National Needs” speech (1961), 3:4, 95
- Kennedy Space Center, 3:97, 237–238, 290
- Kenschaft, Patricia, 3:20
- Kentucky long rifle, 1:35–36
- Kettering, Charles F. (1876–1958), 2:204–205, 215–216, 219
- Kevlar. *See* Bulletproof vest/Kevlar
- Kier, Samuel (1813–1874), 2:90–91
- Kilby, Jack (1923–2005), 3:70–71, 76–77, 100, 215–216
- Kindle e-book reader, 3:251, 258, 265, 312
- Kinematoscope, 2:6, 59, 91, 103, 243
- Knight, Margaret (1838–1914), 2:91–92
- Know-Nothing Party, 1:171
- Knox, Rose Markward, 2:4
- Kolbe, Hermann, 2:18
- Kolff, Willem, 3:180
- Koop, C. Everett, 3:173–177
- Kurzweil, Ray (1948–), 3:291–292
- Kwolek, Stephanie Louise (1923–2014), 3:77–78
- Labor and labor unions
 - Amalgamated Clothing and Textile Workers Union (ACTWU), 2:15
 - Amalgamated Clothing Workers of America (ACWA), 2:14–16
 - American Federation of Labor (AFL), 2:15, 286
 - Baltimore Buttonhole Makers Union, 2:15
 - Chicago Men’s Garment Workers Strike, 2:14–15
 - child labor, 1:162, 298; 2:2, 7, 104–105
 - Congress of Industrial Organizations (CIO), 2:15
 - Factory Girls’ Association, 1:129
 - and Ford, Henry, 2:204
 - International Garment Workers of America, 2:4–5
 - International Ladies’ Garment Workers’ Union (ILGWU), 2:285–287
 - Lady Stitchers’ Union, 2:4, 92–93
 - Lowell Female Labor Reform Association (LFLRA), 1:129, 297–298
 - Operation Dixie (campaign to unionize Southern workers), 2:15
 - Ten-Hour Movement, 1:297–299
 - UNITE HERE, 2:15
 - United Garment Workers of America (UGW), 2:14–16
 - Workers United, 2:15
- Lackoff, Sam, 3:24
- Lacks, Henrietta (1920–1951), 3:78–79
- Lady Stitchers’ Union, 2:92–93
- Lam, Tat, 3:215
- Lamarr, Hedy (1914–2000), 2:290–292
 - primary document: patent for Hedy Lamarr’s Frequency-Hopping System (1942), 2:292
- Land mines, 1:245–246
- Land, Edwin H. (1909–1991), 3:79–80, 117–118
- Lange, Dorothea (1895–1965), 2:292–293
- Larson, John, 2:216–217
- Laser cataract surgery device, 3:213–214
- Lasers, 3:80
- Lavoisier, Antoine, 1:51
- Lawn mower, reel-type, 2:93
- LED lights, 3:81
- Lee, Linda, 3:121
- Lee, “Mother” Ann, 1:196
- Lend-Lease Program (1941–1945), 2:293–294
- Lennox, David (1855–1947), 2:93–94

- Leroux, Henri, 2:18
- Letterman, Jonathan, 1:187–188, 241
- Lewis, Alice Jackson, 1:201
- Lewis, Craig, 3:181
- Lewis, Meriwether, 1:8, 123–125. *See also* Lewis and Clark Expedition
- Lewis and Clark Expedition (1804–1806), 1:123–125
 American Philosophy Society sponsorship for, 1:124
 artifacts housed in Peale Museum, 1:48
 geographic and geological findings of, 1:125
 and Jefferson, Thomas, 1:4, 8, 45, 77, 123–125
 political goals of, 1:123
 primary document: excerpts from expedition journal (1805, 1806), 1:126–127
 Sacagawea as guide to and voting member of, 1:23, 125
 scientific goals of, 1:123–124
 scientific observations and discoveries of, 1:124–125
 social science contribution of, 1:125
 York (African American slave) as voting member of, 1:125
- Li, Min Chiu, 2:261
- Liberty Ships, 2:294–295
- Lichterman (Teitelbaum), Ruth, 3:1, 56
- Lie detector, 2:216–217
- Life Savers candy, 2:217
- Lightning rod, 1:36–37
 primary document: frontispiece and title page of Benjamin Franklin's *Experiments and Observations on Electricity* (1774), 1:37
- Lilienthal, Otto, 2:165, 176
- Lincoln, Abraham, 1:138, 167, 285, 308–309
 assassination of, 1:273
 and construction of U.S. Capitol, 1:305
 first transcontinental telegraph wire received by, 1:296
 floating dry dock patented by, 1:113–114, 228–230
 and Pacific Railway Act (1862), 1:258
 primary document: excerpt from patent application for floating dry dock (1849), 1:229–230
 and steam locomotive, 1:288–290
 and telegraph, 1:257, 296, 310–311
- Lindbergh, Charles, 2:175, 178, 190
- Ling, Helen, 3:121–122
- Linotype machine, 2:94–95
- Linux, 3:221, 292–293
- Liotta, Domingo, 3:181
- Lipman, Hymen, 1:267
- Liquified natural gas (LNG) carrier, 3:82
- Liskov, Barbara (1939–), 3:82–83
- Literacy
 reading, 1:33, 169, 171, 191; 2:54, 285; 3:201, 295
 technology, 3:177, 256
- Lobster trap, 1:127
- Lockheed Martin, 2:178
 primary contractor for Terminal High Altitude Area Defense (THAAD), 3:12
- space shuttle external tank constructed by, 3:237
- stealth technology developed by, 3:139–140
- Long, Crawford Williamson (1815–1878), 1:178, 246–247
 biographical details, 1:246–247
 pioneer of use of sulfuric ether for anesthesia, 1:178, 246–247
- Long arm. *See* Extension arm
- Loom, 1:38–40
 primary document: excerpts from diary of Martha Ballard describing home weaving (1787), 1:39–40
- Loughead, Malcolm, 2:182
- Love, Nancy Harkness, 2:261, 331–332
- Love, William, 2:108
- Love Canal, 2:108
- Lovelace, William Randolph, II, 3:88
- Lowell, Francis Cabot, 1:5, 74, 128, 161–162
- Lowell mill system, 1:5, 61, 74, 128–130, 161–162
 Factory Girls' Association, 1:129
 Lowell Female Labor Reform Association (LFLRA), 1:129, 297–298
 primary document: description of the life of a mill girl (1845), 1:129–130
 Ten-Hour Movement, 1:297–299
- Lucas, Eliza (1722–1793), 1:40–42, 45
 indigo experimentation of, 1:3, 40, 41
 primary document: letter of Eliza Lucas to her father (1741), 1:41–42
- Lucas, George
 Skywalker Ranch, 3:134–135
 Strategic Defense Initiative named after *Star Wars*, 3:239
- Lyceum Movement, 1:168
- Lyman, William Worcester, 2:4, 33–34
- M&M's, 2:295, 300
- M4 Sherman Tank, 2:295–296
- M16 Rifle, 3:83–84
- MacDonald, Thomas, 2:257, 287
- Machine/Gatling gun, 1:247–249
- Macintosh, Charles, 3:115–116
- Madison, James, 1:87
 and canal building, 1:6
 First Bank allowed to expire under, 1:139
 on intellectual property law, 1:136
 on tariffs, 1:138
- Magnetic resonance imaging (MRI), 3:84–85
- Maher, Mary Denis, 1:191
- Maker Faire, 3:254, 293–295
- Manhattan Project, 2:201, 260, 264, 272, 296–297; 3:60–61, 111, 220
 and Calutron Girls, 2:267–268
 and Oppenheimer, J. Robert, 2:303–304
 and Wu, Chein-Shiung, 2:333–334
- Manifest destiny, 1:78, 171
- Mann, Horace, 1:169

- March for Science, 3:295
- Marconi, Guglielmo, 2:5, 171, 236
- Marcus, Siegfried, 2:181
- Margarine, 2:95
- Markkula, Mike, 3:177
- Mars Rover Series, 3:295–297
- Marsh, Albert L. (1877–1944), 2:217–218
- MASER, 3:85
- Masking tape, 1:175; 2:113, 218, 241. *See also* Adhesive tape
- Mason, John Landis
 mason jar invented by, 1:173–174, 249
 salt shaker invented by, 1:267
- Mason jar, 1:173–174, 249
- Masters, Sybilla (c. 1675–1720), 1:42
- Matchbook matches, 2:96
- Mather, Cotton (1663–1728), 1:43–44
- Matulka, B. Rebecca, 3:50–53
- Matzeliger, Jan Ernst (1852–1889), 2:4, 96–97
- Mauchly, John, 3:55, 150–151
- Maxim, Hiram, 1:247–249
- Maxim, Hudson (1853–1927), 2:97
- Maynard, Edward (1813–1891), 1:249–250
- Maynard carbine, 1:250–252
- McClintock, Barbara (1902–1992), 3:86–87
- McCormick, Cyrus (1809–1884), 1:252–254
 primary document: letter from Robert E. Lee regarding
 curriculum at Washington College (1865), 1:253–254
- McCormick, Katherine, 3:31
- McKnight, William L. (1887–1978), 2:218–219
- McLuhan, Marshall, 1:168
- McNeill, Thomas E., 1:222
- McNulty (Mauchly Antonelli), Kathleen “Kay,” 3:1, 56
- Mead, Margaret (1901–1978), 2:297–299
- Mechanical reaper, 1:254–255
- Mercury 13, 3:88
- Merlin, John Joseph, 1:282
- Merrick, Solymon (1806–1852), 1:255
- Metal detector, 2:97–98
- Metal electrode weld, 2:98–99
- Metal windmill, 2:99–100
- Metcalf, Robert (1946–), 3:214–215
 American Arithmometer Company financed by, 2:14
 coinventor of Ethernet, 3:215
 Metcalf’s Law, 3:214
 3Com founded by, 3:215
- Microchip, 3:215–217
- Microsoft, 3:217–218
 competition with Intel, 3:72
 competition with Linux, 3:293
 Internet Explorer, 3:166, 190, 217, 301
 MS-DOS, 3:200, 206, 211, 217
 Windows, 3:166, 200, 211, 217–218, 251–253, 286, 301
 See also Gates, Bill
- Microwave oven, 2:299
- Midgley, Thomas (1889–1944), 2:204–205, 219–220; 3:38
- MIDI (Musical Instrument Digital Interface), 3:297
- Miescher, Friedrich, 3:4, 202
- Military-industrial complex, 3:88–90
 and “big science,” 2:264
- Military technology (Civil War), 1:255–258
 amputations, 1:256
 medical history, 1:256
 photographic documentation, 1:256
 railroad’s impact, 1:257–258
 sanitation, 1:256
 submarines, 1:257
 surgery, 1:256
 systems, 1:256
 telegraph’s impact, 1:256–257
 weaponry, 1:256
- Military technology (post–Civil War through World War I),
 2:100–102
 air balloons, 2:101
 aircraft in WWI, 2:75, 171, 176, 178, 234; 3:48
 machine guns, 2:102
 medical technology, 2:102
 minié bullets, 2:101
 railroad’s impact, 2:101
 submarines, 2:101
 tanks, 2:101
 telegraph’s impact, 2:102
- Military technology (World War II), 2:299–301
 aircraft, 2:189, 223, 234, 255–256, 261–262, 300, 301; 3:7
 ammunition, 2:300
 atomic bombs, 2:300 (*see also* Atomic bombs/nuclear
 weapons)
 DDT, 2:301
 food and nutrition, 2:300
 health and medicine, 2: 300–301
 nylon, 2:301
 radar, 2:300, 301–302, 310, 320
 sonar, 2:300
- Miller, Phineas, 1:99–100, 117, 164, 165
- Miller, Samuel, 1:84
- Milliken, Greg, 3:168
- Milling machine, 1:130–131
- Minuteman I (ICBM), 3:2
- Minsky, Marvin (1927–2016), 3:90–91
- MIT Radiation Laboratory, 2:301–302
- Mitchell, Maria (1818–1889), 1:19, 258–259
- Mobile phone, 3:218–219
- Molina, Mario J., 2:176; 3:38
- Moll, Gerard, 1:199
- Monroe, James, 1:260
- Monroe, Rose Will, 2:314
- Monroe Doctrine, 1:168

- Monsanto, 2:136; 3:9, 19, 172, 273
 Montagnier, Luc, 3:172, 175
 Montague, Hannah Lord, 1:219–220
 Monte Carlo method (computer algorithms), 3:56, 289
 Montgolfier brothers, 2:176
 Moody, Paul, 1:74
 Moog, Robert (1934–2005), 3:91–92
 Moore, Ann (1934–), 3:298
 Moore, Gordon, 3:71–72, 100, 101, 131, 217
 Moore, Hiram, 1:171, 205
 Moore, John Hamilton, 1:137
 Moore's Law, 3:71, 132, 133, 217, 289
 Morey, Samuel (1762–1843), 1:76, 131–132, 148
 Morgan, Garrett (1877–1963), 2:220–221
 Morgan, J. Pierpont, 2:2, 35, 36–37, 58, 61, 74, 107, 160, 169, 324
 Morgan, Mary Sherman (1921–2004), 3:92–93
 Morphine, 2:59
 as anesthesia, 1:179, 187
 discovery of, 1:178
 wartime use of, 1:187
 Morrison, William J.
 cotton candy invented by, 2:45
 first electric car designed by, 3:49, 50, 247
 Morse, Samuel F. B. (1791–1872), 1:78, 260–261; 2:120
 biographical details, 1:260
 correspondence with Mitchell, Marie, 1:259
 and Henry, Joseph, 1:237
 inspired by Humboldt, Alexander von, 1:46
 and telegraph line/cable, 1:202, 226, 260, 261–262, 295
 telegraph invented by, 1:7, 226, 256, 260, 261–262, 236
 See also Morse code
 Morse code, 1:7, 169, 257, 260, 261–262, 295; 2:236, 323; 3:25, 328
 Motion picture camera, 2:102–104
 Motorcycle (pre–World War II), 2:221–222
 Motorcycles, 1:120, 121; 3:36
 Motorola, 2:182, 205–206
 MP3, 3:298–299
 Muller, Paul Hermann, 3:6
 Multitubular boiler, 1:132
 Mural, Frank, 3:55

 Nanotechnology, 3:93–94
 Napalm, 3:94
 Nash-Kelvinator Corporation, 2:182
 National Academy of Sciences (NAS), 1:262–263
 National Advisory Committee for Aeronautics (NACA), 2:223
 National Aeronautics and Space Administration (NASA), 3:94–98
 centers and facilities, 3:97
 creation of, 3:94–95
 primary document: letter of Dwight Eisenhower to Keith Glennan (1960), 3:98
 Project Mercury, 3:88, 95, 96
 Skylab, 3:97, 133–134, 284
 and space science, 3:96
 Terra, 3:96–97
 See also Apollo Project; International Space Station; Space shuttle program; Voyager spacecraft
 National Consumers League, 2:104–105
 National Institutes of Health (NIH), 2:6, 105–106; 3:98, 119
 AIDS research, 2:105; 3:173, 175
 artificial heart program, 3:180
 Human Genome Project funded by, 3:279–280
 Rocky Mountain Labs, 2:240
 National Oceanic and Atmospheric Administration (NOAA), 1:78; 3:144
 National Road, 1:132–134
 National Science Foundation (NSF), 3:98–99
 Nativism, 1:171
 Natural history, 1:44–46
 Natural philosophy, 1:4, 8–9, 31, 44, 237
 Needham, Orwell H., 1:182
 Negroponte, Nicholas (1943–), 3:299–300
 Neoprene, 2:302–303
 Netscape, 3:166, 190, 256, 274, 300–301
 New Deal, 2:213, 251–257
 and Ford, Henry, 2:204
 and Lange, Dorothea, 2:292–293
 Tennessee Valley Authority Electricity Project (TVA), 2:213, 251–252, 328–329
 union support for, 2:286
 Works Progress Administration, 2:213
 See also Hoover Dam
 New Millennium (2000–present), 3:247–254
 alternative energy sources, 3:247–248
 bioprinting, 3:248
 electric cars, 3:247
 laser technology, 3:248
 medical technology, 3:249–250
 open-source software, 2:252
 portable technology, 2:253–254
 search engine technology, 2:252–253
 technology in education, 3:250–251
 technology in music, 3:251–252
 3-D technology, 3:248–249
 New Republic and the Market Economy (1780–1820), 1:71–79
 African technologies, 1:71
 agricultural innovation, 1:73–74
 amateur scientists, 1:77–78
 attitudes toward science, 1:71–72
 Census Act (1790), 1:73
 factory system, 1:74
 immigration's significance, 1:71–72, 74, 76–77

- interchangeable parts, 1:75–76
- medical sciences, 1:75
- shipbuilding, 1:73
- steam power, 1:76–77
- transportation engineering, 1:75–76
- Newbold, Charles, 1:73, 159
- Newton, Isaac, 1:27, 33, 68, 103, 144
- Niagara Falls Power Plant, 2:106–112
 - primary document: excerpt from Nikola Tesla’s commemoration address (1897), 2:108–112
- Niépce, Joseph Nicéphore, 2:31–32
- Nightingale, Florence, 1:88, 89, 187, 256, 263–264, 307
- Nightingale Plan, 1:263–264, 307
- 911 emergency system, 3:8–9
- Noether, Amalie Emmy (1882–1935), 2:224–225
- North, Simeon (1765–1852), 1:76, 243, 264–265
- Nowell, Peter, 3:261
- Noyce, Robert (1927–1990), 3:71–72, 77, 99–102, 131, 215–216
 - primary document: personal interview for the IEEE History Center (1975), 3:100–102
- Nuclear and radiation accidents, 3:102–104
- Nuclear energy/nuclear power plants, 3:219–221
- Nuclear weapons. *See* Atomic bombs/nuclear weapons
- Nye, Bill (1955–), 3:302
- Nystatin, 3:5, 13–14. *See also* Antibiotic

- Obama, Barack, 3:34, 41, 53, 76, 226
 - and Keystone XL pipeline, 3:114
 - napalm ban signed by, 3:94
 - One Maker Faire hosted by, 3:294
- Obama, Michelle, 3:291
- Obsolescence, 2:207; 3:22, 163, 168
- Ochoa, Ellen (1958–), 3:105–106
- Odometer, 1:135
- Office technology (pre–World War II), 2:112–114
- Olds, Ransom Eli (1864–1950), 2:225
- Olmsted, Frederick Law, 2:6, 162, 167, 174
- Olson, Richard, 3:255
- Omnibus System, 1:265–266
- One Laptop per Child, 3:302–303
- Onesimus (fl. 1706–1716), 1:46–47
- oN-Line System (NLS), 3:3
- Onion Router. *See* TOR (The Onion Router)
- Open-source software, 3:221–222
- Oppenheimer, J. Robert (1904–1967), 2:272, 296–297, 303–304, 316; 3:111
- Orshansky, Mollie (1915–2006), 3:106–107
- Orwell, George, 3:169–170, 210
- O’Sullivan, John L., 1:171
- Otis, Elisha Graves, 1:224–225, 256–257; 2:139, 162, 201
- Otis, William, 1:168, 291–292
- Otis Elevator Company, 1:224–225, 256–257; 2:65–66
- Owens, Michael, 2:190–191

- Pacific Railroad Act, 1:276–279; 2:3, 153
- Pacific Telegraph Act (1860), 1:7, 296
- Packet switching, 3:107–108
- Packing tape, 1:175. *See also* Adhesive tape
- Paine, Thomas, 1:76
- Panama Canal, 2:143, 163, 172, 225–232, 279
 - primary document: excerpt from Theodore Roosevelt’s message to Congress after Returning from Canal Zone (1906), 2:228–232
- Paper bag, 2:114
- Paper clip, 2:114–115
- Papermaking machine, 1:266
- Parmly, Levi Spear, 1:75, 102
- Particle accelerator, 3:108–110
 - primary document: press release issued by CERN, the European Organization for Nuclear Research (2012), 3:109–110
- Pascal, Blaise, 1:265
- Patent and copyright statutes, 1:135–137
 - Copyright Act (1790), 1:136
 - and music, 3:298
 - Patent Act (1790), 1:136
 - Patent Act (1836), 1:170
- Paul, Les (1915–2009), 2:270–271, 304–305
- Pauling, Linus “Carl” (1901–1994), 3:34, 110–111
- PayPal, 3:303–304
- Peabody, Elizabeth Palmer, 1:168, 170, 259
- Peale, Charles Willson (1741–1827), 1:47–51
 - primary document: letter to Thomas Jefferson regarding agricultural innovations (1815), 1:48–51
- Pemberton, John “Doc,” 2:43–44
- Pencil eraser, 1:267
- Penicillin, 2:6, 256–257, 300–301, 306–307; 3:5, 13
- Penn, Sean, 3:134–135
- Penn, William
 - Charter of Privileges (1701), 1:10
 - Governor’s Mill built for, 1:42
 - scientific legacy of, 1:72
- Pennington, Mary Engle (1872–1952), 2:232
- Pepper (and salt) shaker, 1:267
- Perkins, Jacob (1766–1849), 1:76, 161, 267–268
- Perkins, William C., 1:234
- Perlman, Radia (1951–), 3:222–223
- Permanent press fabric, 3:111–112
- Personal computer (PC), 3:223–224
- Petroleum industry (post–World War II), 3:112–114
- Petroleum industry (pre–World War II), 2:233–234
- PGP Encryption, 3:303–304
- pH Meter, 2:307–308
- Phelps, George M., 1:272

- Phonograph, 2:115–119, 208–210
 and Bell, Alexander Graham, 2:117, 209
 invented by Edison, Thomas, 2:115–118, 208–210
 primary document: roll call of companies at the
 Phonograph Convention in Chicago (1890), 2:119
- Photocopier, 2:307–308
- Photographic film, 2:120–121
- Photography. *See* Camera
- Pierce, William, 1:11
- Pinball and arcade games, 2:308–309
- Pinckney, Eliza Lucas. *See* Lucas, Eliza
- Pincus, Gregory, 3:31
- Pipe wrench, 2:121
- Piria, Raefele, 2:18
- Pixii, Hippolyte, 2:9
- Plasma arc welding, 3:114–115
- Plastic wrap, 2:256, 301, 309
- Plastics, 3:115–117
- Platform scale, 1:168, 268–269
- Player piano, 1:121–122
- Pneumocystis carinii pneumonia (PCP), 3:171, 173. *See also*
 AIDS research
- Polaroids, 3:79–80, 117–118
- Polio vaccine, 3:54, 118–119, 124, 125–126, 152
- Polished steel plow, 1:269
- Pong, 3:20–22, 119–120, 321, 325
- Poplawski, Stephen J., 2:189
- Pop-up toaster, 2:234–235
- Portable transistor radio, 3:120–121
- Portland cement mortar, 2:122–123
- Post-Cold War Era (1980–1999), 3:163–170
 ARPANET and Internet, 3:164–165
 cloning, 3:166
 computer browsers, 3:166
 computers, 3:165–166
 consumer electronics, 3:166–167
 consumerism and choice, 3:163–167
 entertainment advances, 3:167
 hacking, 3:168
 journalism and information transmission, 3:168
 mobile phones, 3:167
 myth of “millennium meltdown” (Y2K), 3:169
 myth of “paperless office,” 3:168–169
 obsolescence, 3:163, 168
 and Orwell, George, 3:169–170
 rate of technological innovation, 3:163
 smart car technology, 3:167–168
 and Soviet Union, 3:163–164
- Practical ocean navigation, 1:137–138
- Priestley, Joseph (1733–1804), 1:51–52
 biographical details, 1:51
 carbonated water created by, 1:51; 2:141
 influence on study of ecology, 1:51
 nitrous oxide experiments, 1:178
 oxygen discovered by, 1:51
- Printing, 1:269–271
 electric typewriters, 2:173; 3:61–62, 69
 first printing press in America, 1:32–33
 Gutenberg’s printing press, 1:270–271
 history of, 1:270–271
 Jefferson’s portable printing press, 1:122
 laser printing, 1:271; 3:159, 249
 Linotype machine, 2:94–95
 movable type, 1:270
 photocopying, 2:307; 3:158–160, 168
 QWERTY keyboard, 2:155–156
 rotary printing press, 1:169, 174
 typewriter, 1:271; 2:5, 155–156
 woodblock printing, 1:270
 See also 3-D printing
- Printing telegraph, 1:169, 271–272, 310
- Progressive Era and the Roaring Twenties (1900–1929),
 2:169–175
 automobile advances, 2:169–170
 communications and media advances, 2:171
 daily life advances, 1:172–173
 film and photography, 2:171
 health-related advances, 2:175
 medical and health advances, 2:172–173, 175
 Panama Canal, 2:172
 Taylorism, 2:146–147, 170, 208
 technological challenges of urbanization, 2:173–175
 transportation advances, 2:169–170
 and wealth, 2:171–172
 Wright brothers’ inaugural airplane flight, 2:170–171
- Pullman, George Mortimer (1831–1897), 1:273, 290
- Pullman car. *See* Railroad sleeping car
- Punch card tabulator, 2:123
- Pure Food and Drug Act (1906), 3:18
- Puritanism, 1:2, 12, 43, 72, 85–86
- Pushpin, 2:113, 235–236
- Putting-out production system, 1:4, 5
- Quadruplex telegraph, 2:124–125
- Quakerism, 1:13, 42, 44–45, 72, 101, 201
- Quantum science, 3:304–305
- Queeney, John Francis, 2:136
- Quinby, Moses, 1:24
 primary source: excerpt from *Mysteries of Bee-Keeping Explained* on use of bee smoker, 2:24–25
- QWERTY layout. *See* Typewriter and QWERTY
- Radar, 2:309–310
- Radio, 2:236–240
 primary document: “Radio’s Real Uses” by E. E. Free,
 science editor for *The Forum* (1926), 2:239–240

- Radioplane Company, 3:48
- Railroad refrigerator car, 2:125–126
- Railroad sleeping car and Pullman car, 2:126–127
- Railroad switch systems, 2:127–128
- Railroad T-rail and tie, 1:168, 273–274, 293
- Railroads, 1:274–279
- Pacific Railway Act (1862), 1:258
 - primary document: Pacific Railway Act (1862), 1:276–279
 - Transcontinental Railroad, 1:208–209, 258, 275, 288–289, 296; 2:3, 153–155
 - and war, 1:257–258, 275; 2:101
- Rains, Gabriel, 1:245–246
- Ratchet wrench, 1:279–280
- Reagan, Ronald, 3:59, 89–90, 100, 173–175, 245
- and International Space Station, 3:280
 - and Strategic Defense Initiative (SDI or “Star Wars”), 3:12, 90, 239–240
- Reed, Ezekiel, 1:76
- Refrigerator, 2:310–311
- Relay, 1:280
- Remington Rand, Inc., 3:1, 151, 189
- Repeating rifle, 1:280–282
- Report on Manufactures* (1791), 1:72, 138–139, 284
- RFID labels, 3:305–307
- Richards, Ellen Swallow (1842–1911), 2:128–129
- Richardson, J. J., 1:280
- Richter scale, 2:311
- Rickover, Hyman, 3:128–129
- Ride, Sally (1951–2012), 3:224–226
- Ritchie, Dennis (1941–2011), 3:226–229, 313–316
- primary document: abstract for “The Development of the C Language” by Dennis Ritchie (1993), 3:227–229
- Rittenhouse, David (1732–1796), 1:8, 28, 52–54, 45, 73, 137
- biographical details, 1:52
 - diffraction grating created by, 1:52, 103–104
 - primary document: letter from Thomas Jefferson (1778), 1:53–54
- Ritty, James, 2:42
- River steamer, 1:139–140
- RNA (ribonucleic acid), 3:4
- Robber barons, 1:276; 2:34
- Robbins, Frederick C., 3:4, 54
- Roberts, Macie, 3:121
- Roberts, Nathan, 1:76
- Robotic surgery, 3:229–232
- primary document: letter from Acting District Director of the FDA to President of Intuitive Surgical Inc. on the regulation of robotic surgery (2013), 3:230–232
- Rock, Arthur, 3:71
- Rock, John, 3:31–32
- Rockefeller, John D., 2:2, 160
- Rocket Girls of JPL, 3:121–123
- primary document: press release announcing Eleanor F. Helin’s naming to WITI Hall of Fame (1998), 3:122–123
- Rocketry (pre–Space Age), 2:311–313
- Rocky Mountain Laboratories, 2:240
- Roebbling, Emily (1843–1903), 2:129–133
- biographical details, 2:129
 - primary document: photograph of promenade on Brooklyn Bridge, 2:131
 - role in construction of Brooklyn Bridge, 2:30, 129–131, 132
- Roebbling, John (1806–1869), 2:30–31, 131–132
- biographical details, 2:131
 - designer of Brooklyn Bridge, 2:131–132
- Roebbling, Washington A., 2:30, 130, 132
- Rogallo, Francis Melvin (1912–2009), 3:123–124
- Rohwedder, Otto Frederick, 2:191
- Roll film, 2:133
- Roller coaster, 2:133–134
- Roller skates, 1:282–283
- Roosevelt, Eleanor, 2:104, 331
- Roosevelt, Franklin D.
- as assistant secretary of the navy, 2:223
 - and Carver, George Washington, 2:40
 - and Einstein, Albert, 2:201, 260, 272
 - Executive Order 8802 (prohibiting racial discrimination in the national defense industry), 3:154
 - and England’s Tizard Mission, 3:331
 - first American president to appear on television, 2:163
 - fireside chats, 2:237, 254
 - and Ford, Henry, 2:204
 - and Hoover Dam, 2:279, 280–283
 - and interstate highway system, 2:287
 - and Lend-Lease Act, 2:293–294
 - and Manhattan Project, 2:202, 260, 272, 296
 - and MIT Radiation Laboratory, 2:301–302
 - and National Cancer Act (1937), 3:261
 - primary document: Hoover Dam dedication speech, 2:280–283
 - Rural Electrification Administration (REA) created by, 2:252
 - shift from “Dr. New Deal” to “Dr. Win the War,” 2:256
 - and Tennessee Valley Authority Electricity Project (TVA), 2:328
 - See also* New Deal
- Roosevelt, Nicholas, 1:76–77, 293
- Roosevelt, Theodore
- Bureau of Reclamation established under, 2:277–278
 - as first modern president, 2:7
 - and military-industrial complex, 3:89
 - New Nationalism of, 2:172
 - opposition to ban on saccharine by, 2:136; 3:18
 - and Panama Canal, 2:227–232
 - primary document: excerpt from message to Congress after returning from Panama Canal Zone, 2:228–232
 - and Reclamation Act (1902), 2:278
- Root, Elisha K., 1:202–203, 204
- Ropes, Hannah, 1:190
- Rosie the Riveter, 2:313–316

- primary document: excerpt from interview with Maria Isabel Solis (2003), 2:315–316
- Rotary hook (for sewing machines), 1:283
- Rotary washing machine, 2:134–135
- Rotheim, Erik, 2:176
- Rous, Francis Peyton, 3:261
- Rowing machine, 2:135
- Rowland, Frank Sherwood, 2:176; 3:38
- RU-486/Plan B, 3:307–308
- Rucker ambulance, 1:283–284
- Rudy, Marion Frank, 3:11
- Ruggles, John, 1:170
- Rumford Fireplace, 1:141, 158–159
- Rumsfeld, Donald, 3:19
- Rush, Benjamin (1746–1813), 1:142–145
primary document: excerpt from medical writings of Benjamin Rush (1805), 144
- Sabin, Albert B. (1906–1993), 3:54, 119, 124–125
- Saccharine, 2:135–137; 3:18
controversy and regulation, 2:136–137
and Roosevelt, Theodore, 2:136; 3:18
Sweet’ n Low (brand name), 2:137, 3:18
- Safety pin, 1:284
- Safety razor, 2:240–241
- Salicylic acid. *See* Aspirin
- Salk, Jonas (1914–1995), 3:54, 119, 124, 125–126, 152
- Salt shaker. *See* Pepper (and salt) shaker
- Sänger, Eugen, 3:237
- Sanger, Larry, 3:250
- Sanger, Margaret, 3:31
- Saquinavir, 3:172. *See also* AIDS research
- Sarnoff, David, 2:171
- Satellite radio, 3:232–233
- Satellites and space probes, 3:126–127
- “Saugus pot,” 1:54–55
- Scheele, Carl Wilhelm, 1:51
- Schenck, John F., 1:78
- Schlatter, John, 3:18
- Schooner, 1:55–56
- Schultz, Jane E., 1:190–191
- Schwinger, Julian (1918–1994), 2:316–317
- Science Friday*, 3:308
- Scientific management (Taylorism), 2:146–147, 170, 208
- Scotch Tape, 2:113, 218, 241. *See also* Adhesive tape
- Scott, Charlotte, 3:20
- Scott, Ewin, 2:134
- Scott, Mike, 3:177
- Scott, Richard, 2:330
- Scott, Thomas, 2:34
- Scott, Walter, 2:47–48
- Scott, Winfield, 1:213
- Screw-cutting lathe, 1:145
- Sculley, John, 3:177–178
- Seaborg, Glenn, 2:260
- Self-driving cars, 3:233
- Selfridge, Thomas, 2:178
- SEMATECH, 3:234–235
- Simple, Ellen Churchill (1863–1932), 2:317–318
- Sertürner, Friedrich, 1:178
- SETI (Search for Extraterrestrial Intelligence), 3:308–311
- Seward, William, 1:10
- Sewell, William, 3:180
- Sewing machine, automated, 1:284–286
- Sewing pattern, 1:286–287
- Shapiro, Bob, 3:19
- Sharecropping, 2:3
- Sharpless, Thomas Kite, 3:55
- Shaw, Robert F., 3:55
- Shepard, Alan, 3:4, 88
- Sherman, Patsy O’Connell (1930–2008), 3:127–128
- Shippingport Atomic Power Station, 3:128–129
- Shockley, William, 3:1, 131, 148
- Sikorsky, Ivan, 2:276–277
- Silent Spring* (1962), 2:288–289; 3:6–7, 18, 36–38, 129–130.
See also Carson, Rachel (1907–1964)
- Silicon Valley, 3:130–132
- Silo, 2:137–138
- Silver, Bernard, 3:25
- Silverman, Jacob, 3:93
- Simms, Frederick, 2:183
- Singer, E. C., 1:288
- Singer, Isaac
first commercially viable sewing machine developed by, 1:6, 285–286
marketing skills of, 1:285
patent battle with Howe, Elias, 1:6, 285
- Singer Sewing Machine Company, 1:285, 303; 3:25
- Single-chip microprocessor, 3:132–133
- Skylab, 3:97, 133–134, 284
- Skyscraper, 2:138–140
- Skywalker Ranch, 3:134–135
- Slater, Hannah Wilkinson (1775–1812)
Almy, Brown, & Slater, 1:101
first woman to receive U.S. patent (two-ply cotton thread), 1:5, 74, 101
Quaker background of, 1:45, 101
- Slater, Samuel (1768–1835), 1:5, 45, 146–148
Almy, Brown, & Slater, 1:101, 147
biographical details, 1:146
carding machine created by, 1:146
first U.S. cotton spinning mill (Pawtucket, Rhode Island), 1:101, 146–147, 148
hydropowered yarn-spinning factories, 1:74, 101, 147
Samuel Slater and Company, 1:147
Slater mill system (also Rhode Island system), 1:61, 74, 101, 146–147, 161
Slaterville, Rhode Island, founded by, 1:5

- water frame spinning machine created by, 1:146
and workforce and labor conditions, 1:147
- Smallpox, eradication of, 3:135–136
- Smallpox inoculation, 1:56–59
primary document: George Washington's order for soldiers to receive inoculation (1778), 1:58
primary document: letter of Edward Rowse to Thomas Jefferson suggesting possibility of vaccines for other diseases (1805), 1:58–59
- Smartphone and 3G network, 3:311–312
- Smith, Adam, 1:138; 2:179, 180
- Smith, Al, 2:51, 239
- Smith, Andrew, 2:77
- Smith, C. Harold, 2:45–46, 186–187
- Smith, Dave (engineer and synthesizer designer), 3:297
- Smith, David M. (modern clothespin patent), 1:196
- Smith, Francis Pettit, 1:293
- Smith, Fred, 2:225
- Smith, Hamilton (genetic researcher), 3:203
- Smith, Hamilton (inventor of rudimentary rotary washing machine), 2:134
- Smith, Horace, 1:281
- Smith, John Lawrence, 1:244
- Smith, Lucien, 2:20
- Smith, Richard, 2:263
- Smith, Roe, 1:131
- Smith, Sam (co-inventor of Scotchgard Fabric Protector), 3:127
- Smith, Samuel (copper tycoon), 2:225
- Smith & Wesson Company, 1:281
- Smithing. *See* Goldsmiths; Iron- and silversmithing
- Smithsonian Institution
gum with bar code at, 3:25
and Henry, Joseph, 1:7, 237–238
original UNIVAC at, 3:151
space shuttles at, 3:238
and Wright brothers, 2:165, 177
- Smoke detector, 3:136–137
primary document: Chris P. Borreson's account of the Iroquois Theater Fire (1904), 1:137
- Snyder (Holberton), Frances "Betty," 3:1, 56
- Soda fountain, 2:140–141
- Solar compass, 1:287. *See also* Equatorial sextant
- Solar energy, 3:235–237
- SONAR, 2:318–319
- Sorensen, Charles Emil, 2:179–180
- Sorensen, Edward M., 3:48
- Space science and technology, 3:137
primary document: account of astronaut David Alexander Wolf voting in space (1997), 3:138
- Space shuttle, 3:96, 237–239
- Spar torpedo, 1:288
- Species extinction, 1:47, 175, 176; 3:250
- Spindler, Michael, 3:178
- Spinning wheel, 1:59–61
primary document: "Address to the Ladies" urging American women to boycott British goods (1767), 1:61
- Spirit of St. Louis*, 2:175, 178, 190
- Spork, 2:141–142
- Sprague, Frank Julian, 2:5, 242
- Sputnik 1, 2:313; 3:2–3, 14, 16, 89–90, 93, 94–95, 126, 284
- Sputnik 2, 3:3, 93, 126
- Standard Oil, 2:2, 233–234
- Stanford, Leland, 1:275, 276, 290
- Stanley, William, Jr., 2:9–10
closed core transformer perfected by, 2:9, 64
and Great Barrington Electrification, 2:9, 62
primary document: AIEE member biography for, 2:10
Stanley Manufacturing Company founded by, 2:9
at Westinghouse Electric Company, 2:9, 64
- Stanley Home Products, 3:157
- Stanley Motor Carriage Company, 1:148
- Stealth technologies, 3:138–140
- Steam engine, 1:148–149
patent of Watt, James, 1:107, 148, 151, 167, 289, 293
- Steam locomotive, 1:288–291
Best Friend steam engine, 1:181
- Steam shovel, 1:291–292
- Steam tractor, 1:149–150
- Steamboat, 1:150–154
primary document: newspaper announcement of Fulton's steamboat (1807), 1:153–154
primary document: Dickens's account of ride on steamboat (1842), 1:154
- Steel arched bridge, 2:142–143
- Stephenson, John, 1:239, 265
- Stethoscope, binaural, 2:143–144
- Stetson. *See* Cowboy hat (Stetson)
- Stevens, Edwin, 1:274, 293–294
- Stevens, John, 1:274, 292–293
- Stevens, Robert Livingston (1787–1856), 1:292–294
biographical details, 1:292–293
first U.S. locomotive built by, 1:293
railroad T-rail designed by, 1:168, 274, 293
steamship and steam ferry designs of, 1:76, 115, 274, 293
- Stewart, Philo Penfield, 1:207–208
- Stockyards, 2:144–145
primary document: photograph of Chicago's Union Stock Yards (1907), 2:145
- Stoddard, Joshua, 1:183–185
- Stone, Edward, 2:18
- Stoneman, George, 1:185
- Stoner, Eugene, 3:83, 84
- Stowe, Harriet Beecher, 1:170
- Strassman, Fritz, 2:260
- Strategic Defense Initiative (SDI), 3:12, 90, 239–240
- Strauss, Joseph, 2:274–276
- Strauss, Levi (1829–1902), 1:294; 2:15, 84–86

- Street lighting, 1:62
- Stuart, Gilbert, 1:10
- Studebaker Corporation, 2:182, 264
- Sturgeon, William, 1:199, 261
- Sturvaden, Clarence, 2:258
- Submarine, 1:154–155
- Submarine technology, 2:319–320
- Subway system of New York City, 2:242–243
- Sullivan, Louis, 2:174
- Sullivan, Thomas, 2:321, 322
- Sullivan, William, 2:176
- Superconductivity, 3:140–141
- Supersonic Pressure Tunnel, 3:73
- Suspension bridge, 1:155–157
- Sustainable agriculture, 3:240–242
- Sutherland, John Buie, 2:3, 125
- Swim fins, 1:62–63
- Swivel chair, 1:157–158
- Szilard, Leo, 2:201, 260, 296
- T-rail. *See* Railroad T-rail and tie
- Taft, Howard, 2:178
- Talbot, William Henry Fox, 2:32, 120
- Talking movies, 2:243–245
- Tampon, 2:320–321
- Tape measure, 2:146
- Tarrant, Robert, 2:114
- Tarter, Jill (1944–), 3:312–313
- Taussig, Helen (1898–1986), 3:141–143
- Taylor, Frederick (1856–1915), 2:146–147, 161, 170, 173
- TCP/IP (Transmission Control Protocol/Internet Protocol), 3:3, 107, 208, 300. *See also* Internet Protocol (IP); Transmission Control Protocol (TCP)
- Tea bag, 2:321–322
- Telegraph, 1:294–297
- Atlantic Telegraph Company, 1:226–227, 302
- invention of, 1:7, 226, 256, 260, 261–262, 236
- and Lincoln, Abraham, 1:257, 296, 310–311
- primary document: act authorizing construction of a transcontinental telegraph (1855), 1:297
- printing telegraph, 1:169, 271–272, 310
- Western Union Telegraph Company, 1:310–311
- Telenet, 3:3
- Telephone, 2:322–325
- first practical telephone credited to Bell, Alexander Graham, 2:5, 26–27, 322–325; 3:329
- mobile phone, 3:218–219
- touch-tone phones, 3:145
- Telephone switching, computerized, 3:143–144
- Television, 2:325–328
- Ten-Hour Movement, 1:297–299
- primary document: excerpt from preamble and constitution of the Lowell Female Labor Reform Association (1846), 1:298–299
- Tennessee Valley Authority Electricity Project (TVA), 2:328–329
- Terry, Eli, 1:74
- Tesla, Nikola (1856–1943), 2:9, 57, 58, 61, 62, 64, 147–149
- AC induction motor patented by, 2:10–12, 148–149
- biographical details, 2:147
- and Niagara Falls Power Plant, 2:107
- primary document: excerpt from commemoration address for Niagara Falls Power Plant, 2:108–112
- Thayer, Nathaniel, 1:178
- Thomas, David, 1:76
- Thomas, Valerie (1943–), 3:144
- Thomas, Vivien Theodore (1910–1985), 2:329–331
- Thomas de Colmar, Charles Xavier, 2:113
- Thompson, Benjamin (Count Rumford) (1753–1814), 1:158–159
- biographical details, 1:98, 158
- coffee percolator invented by, 1:98–99
- Rumford fireplace invented by, 1:141, 158–159
- Thompson, Ken (1943–), 3:313–316
- primary document: interview with Ken Thompson, inventor of UNIX (2011), 3:314–316
- Thompson Ramo Woolridge (TRW), 3:255
- Thoreau, Henry David, 1:46, 168
- Thornton, William, 1:304–305
- 3-D printing, 3:316–317
- as “additive manufacturing” (AM), 3:316
- bioprinting, 3:248, 317
- 3-D technology
- bioprinting, 3:248, 317
- Google Earth, 3:275
- and medicine, 3:250
- 3-D filmmaking, 3:248
- 3-D printing, 3:316–317
- 3-D television, 3:248
- Three-piece iron plow, 1:159–161
- primary document: petition to Congress for renewal of Jethro Wood’s patent (1846), 1:160–161
- Three-wheel clock, 1:63–64
- primary document: James Ferguson’s description of Benjamin Franklin’s three-wheel clock (1773), 1:64
- Tiananmen Square protests, 3:164
- Ticker tape, 2:149
- Tinsmiths, 1:222, 230. *See also* Iron- and silversmithing
- Tizard Mission, 2:331
- Tocqueville, Alexis de, 1:169
- Tom Thumb* locomotive, 1:7, 150, 289; 2:150–152
- primary document: John Latrobe’s description (1830), 2:150–152
- Toothpaste, 1:299–301
- TOR (The Onion Router), 3:318
- Torpedo, 1:301–302
- Torrey, John, 1:78
- Torvalds, Linus (1969–), 3:318–319

- Touch-tone phones, 3:145
- Track-type tractor, 2:152
- Traffic light, electric, 2:245–246
- Trans-Alaska Pipeline, 3:145–147
 - primary document: bill to reform the Trans-Alaska Pipeline System Authorization Act (1989), 3:146–147
- Transatlantic cable, 1:302–303
- Transcendental Movement, 1:168, 170–171
- Transcontinental Railroad, 1:208–209, 258, 275, 288–289, 296; 2:3, 153–155
- Transistor radio, 3:148–149
- Transmission Control Protocol (TCP)
 - creation of, 3:3
 - and early Internet, 3:208
 - and packet switching, 3:17, 107
 - TCP/IP, 3:3, 107, 208, 300
- Transverse shuttle, 1:303
- Tremblay, Bob, 3:24
- Triangle Shirtwaist Factory Fire (1911), 2:5, 285
- Trinity of personal computers, 3:223–224
- Trinity test (first U.S. nuclear test), 2:260, 272, 297, 303
- Triode tube, 2:24
- Truman, Harry S., 2:303; 3:311
 - and bombing of Hiroshima and Nagasaki, 2:260–261
 - and creation of hydrogen bomb, 2:260, 283, 297; 3:89
 - and National Science Foundation, 3:99
- Trump, Donald, 3:278, 295, 323
- Turbine engine, gas powered, 2:247
- Turtle* submarine, 1:17–18, 65–66, 301
 - action in American Revolution, 1:17–18, 65
 - primary document: engraving of American *Turtle* (1775), 1:18
 - primary document: letter from David Bushnell to Thomas Jefferson regarding experiments with submarines (1787), 1:66
- TV dinner, 3:149
- Twain, Mark, 2:1, 2
- Twine knotter, 1:304
- Twine self-binding harvester, 2:155
- Twist drill, 1:304
- Typewriter and QWERTY, 1:271; 2:155–156
 - electric typewriters, 2:173; 3:61–62, 69
 - and industrialization of leisure, 2:5
- Tyson, Neil deGrasse (1958–), 3:319–321
- UAVs. *See* Drones
- Unimate/industrial robot, 3:150
- United States Capitol Building, construction of, 1:304–306
 - design competition for, 1:304–305
 - fire during War of 1812, 1:305
 - rebuilding of, 1:305
 - renovation (2013), 1:305–306
- United States Constitution, 1:4, 25, 304–306
 - commerce clause in, 1:139
 - Constitutional Convention (1776), 1:53
 - Constitutional Convention (1787), 1:26, 112, 136
 - on copyright and patent law, 1:136
 - on monopolies, 1:136
 - Nineteenth Amendment, 1:309
 - United States Patent Board, 1:4, 107
 - United States Sanitary Commission (USSC), 1:187, 306–307
 - Universal Automatic Computer (UNIVAC), 3:1, 150–151
 - and A-0 program, 3:1
 - cost of, 3:151
 - creation of, 3:65, 150–151
 - purpose of, 3:69, 150
 - size of, 3:151
 - sold to U.S. Census Bureau, 3:151, 189
 - Unmanned aerial vehicles (UAVs). *See* Drones
 - URL, 3:184, 208
- Vaccines, 3:151–153
 - eradication of smallpox, 3:135–136
 - polio vaccine, 3:54, 118–119, 124, 125–126, 152
 - smallpox inoculation, 1:56–59
- Vail, Alfred, 1:7, 169, 260–262, 271–272, 295
- Vapor-compression refrigerator, 1:161
- Varmus, Harold Eliot, 3:261
- Vaughan, Dorothy (1910–2008), 3:153–155
- Vaux, Calvert, 2:6
- Velocipede, 2:156–157
- Venable, James, 1:178
- Vending machine, 1:157–158
- Vibrator, 2:158–159
- Victor Adding Machine Company, 2:114
- Victor Talking Machine Company, 2:29, 209–210, 117
- Victoria, Queen
 - Eads, James B., recipient of Albert Medal of the Royal Society of Arts from, 2:143
 - fan of carpet sweepers, 2:38
 - first official telegraphic exchange from, 1:302
 - phonograph message recorded by, 2:117
- Victorian Era
 - and Central Park (New York City), 2:5–6
 - and Columbian Exposition (1893, Chicago), 2:5–6
 - corsets as erotica in, 1:212
 - decorum in, 2:5–6
 - labor relations in, 2:154
 - time as commodity in, 2:5
 - See also* Industrialism, Reconstruction, and the Gilded Age
- Victrola. *See* Gramophone/Victrola
- Video game, 3:321–323
- Video streaming services, 3:323
- Virtual reality (VR), 3:323–325
- Vocoder, 3:155

- Vogt, Peter K., 3:261
 Voight, Henry, 1:76
 Volwiler, Ernest H., 1:179
 Voyager spacecraft, 3:14, 16, 75, 96, 122, 127, 144, 156
 Vulcanization, 1:307–308
- Wadsworth, Augustus, 3:13
 Wagner, David, 3:32
 Wales, Jimmy, 3:250
 Walker, Mary (1832–1919), 1:308–309
 Waltham-Lowell textile system, 1:5, 61, 74, 128–130, 161–162, 297–298
 Wang, An (1920–1990), 3:325–326
 Washing machine, electric, 2:247–248
 Washington College, 1:253–254
 Washington, George
 almanacs used by, 1:12
 American Philosophical Society member, 1:8
 and American Revolution, 1:18, 116, 138
 and canal building project, 1:6, 95, 106–107
 Census Act (1790) signed by, 1:73
 forgiveness of Greene family's debts, 1:117
 glasses designed for by Franklin, Benjamin, 1:52
 innovation encouraged by, 1:74
 and National Road, 1:76, 132–133
 portraits of by Stuart, Gilbert, 1:10
 primary document: letter from Robert Fulton urging support of canal construction, 1:106–107
 primary document: order for all soldiers to receive smallpox inoculation, 1:58
 Rittenhouse, David, appointed as inaugural director of U.S. Mint by, 1:53
 on Turtle submarine, 1:66
 U.S. Capitol Building project begun by, 1:304–305
 Washington, Martha, 1:39, 101
 Water heater, 2:159–160
 Waterhouse, Benjamin, 1:45, 75
 Watson (computer), 3:191
 Watson, James, 3:5, 202
 Watson, Thomas, 2:26–27, 323; 3:68
 Watt, James, 1:107, 148, 151, 167, 289, 293, 143
 Weather Bureau, 2: 7–8
 Webster, Daniel, 1:233
 Webster, Noah, 1:135, 169
 Wedgwood, Thomas, 2:32
 Weinberg, Alvin M., 2:264–265; 3:104
 Welding, alternating current, 2:248–249
 Welding, automatic, 2:249
 Weller, Thomas H., 3:4
 Wells, Horace, 1:178
 Wells Fargo, 1:172; 3:307
 Welter, Barbara, 1:170
 Wescoff (Meltzer), Marilyn 3:1, 56
 Western Union Telegraph Company, 1:310–311
 Westinghouse, George, 2:3, 36, 160–161
 and gas transmission, 2:73
 and Niagara Falls Power Plant, 2:107–108, 110
 and railroad switch system, 2:127
 and Stanley, William, 2:9, 64
 support for alternating current (AC), 2:58, 62, 107, 148
 Westinghouse air brake, 2:160–161
 Wharton, John C., 2:45
 Wheel cipher, 1:162–163
 primary document: excerpts from Thomas Jefferson's notes on the wheel cipher (undated), 1:163
 White, Canvass, 1:76, 105
 White, Ellen, 1:236
 White, Lydia, 1:201
 “White out,” 3:61–62
 Whitney, Eli (1765–1825), 1:82, 163–166, 204
 cotton gin invented by, 1:5, 61, 86, 99–100, 117, 164
 and development of interchangeable parts, 1:74, 118–119, 131
 and development of milling machine, 1:130, 131, 164–165
 primary document: letter to his father regarding ginning of cotton (1793), 1:165–166
 Whiton, David Erskine (1825–1904), 1:67–68
 Wiley, Harvey, 2:136; 3:18
 Wilkins, Maurice, 3:5
 Willard, Emma, 1:170
 Willard, Simon, 1:87
 Williams, Roberta (1953–) and Ken (1954–), 3:327–328
 Wilson, Allen Benjamin, 1:283
 Wilson, James, 3:203
 Wilson, Joseph C., 3:158
 Wilson, Woodrow, 1:20, 283, 285; 2:163, 172, 223; 3:142
 Wilson Dam, 2:328
 Wind energy, 3:242–244
 Windmill. *See* Metal windmill
 Winthrop, John (1714–1779), 1:68–69
 primary document: observation of the planet Venus (1761), 1:69
 Wireless communication, 3:328–330
 Wise, Brownie (1913–1992), 3:157–158
 Women's Airforce Service Pilots (WASPs), 2:331–332
 authorized and overseen by Arnold, Hap, 2:261, 331–332
 and Avenger Field (World War II WASPs home), 2:261–262
 deactivation of, 2:262, 332
 merging of WAFS and WFTD to form WASP, 2:262, 332
 primary document: letters of Mary Anna Martin Wyall, WASP pilot trainee (1944), 2:262–263
 Women's Auxiliary Ferrying Squadron (WAFS), 2:261–262, 332
 Women's Flying Training Detachment (WFTD), 2:261–262, 332
 Wood, Carl, 3:70

- Wood, Jethro, **1**:160
- Wood, John C., **2**:183
- Woodbury, Robert, **1**:131
- Woodland, Norman, **3**:25–26
- Woodruff, Robert W., **2**:44
- Woodward, John, **2**:284
- World Wide Web. *See* Internet
- World's Columbian Exposition (1893, Chicago), **2**:58, 107, 162, 167
- AC generator and transformer at, **2**:58, 63, 107
- dishwashing machine at, **2**:4, 48–49
- Ferris wheel at, **2**:66, 67–68
- Kinematoscope at, **2**:6, 243
- refracting telescope at, **2**:167
- Rumford Kitchen at, **1**:141–142, 223; **2**:129
- zipper at, **1**:311
- World's Fairs, **1**:218, 224, 253; **2**:5–6, 66, 161–164, 253; **3**:28, 57–58, 145, 155
- female participation in, **2**:4, 193
- history of, **2**:161–164
- IBM pavilion at 1964 World's Fair, **3**:68
- Louisiana Purchase Exposition (1904, St. Louis), **2**:45, 67, 162–163, 187
- Philadelphia Centennial Exposition (1876), **2**:112, 134, 161
- See also* Great Exhibition of 1851 (London); World's Columbian Exposition (1893, Chicago)
- Wozniak, Steve (1950–), **3**:158, 177–180, 209, 223, 244–245
- Wright, Wilbur (1867–1912) and Orville (1871–1948), **2**:164–166, 223
- first powered, controlled aircraft, **2**:7, 164–166, 170–171, 178, 312
- primary document: entry from Orville Wright's diary, **2**:166
- Wu, Chien-Shiung (1912–1997), **2**:333–334
- Wyll, Mary Anna Martin, **2**:262–263
- Xerox Corporation, **3**:132, 158–160, 190, 214–215, 264, 292
- primary document: patent for xerography (1956), **3**:159–160
- Y2K, **3**:169
- Yale, Linus Jr., **1**:216
- Yalow, Rosalyn Sussman (1921–2011), **3**:160–162
- Yerkes, Charles Tyson, **2**:67, 167
- Yerkes Observatory, **2**:166–168
- YouTube, **3**:330
- Zipper, **1**:311

Technical Innovation in American History

Technical Innovation in American History

An Encyclopedia of Science and Technology

VOLUME TWO: RECONSTRUCTION THROUGH
WORLD WAR II

ROSANNE WELCH AND PEG A. LAMPHIER, EDITORS



An Imprint of ABC-CLIO, LLC
Santa Barbara, California • Denver, Colorado

Copyright © 2019 by ABC-CLIO, LLC

Every reasonable effort has been made to trace the owners of copyright materials in this book, but in some instances this has proven impossible. The editors and publishers will be glad to receive information leading to more complete acknowledgments in subsequent printings of the book and in the meantime extend their apologies for any omissions.

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, except for the inclusion of brief quotations in a review, without prior permission in writing from the publisher.

Library of Congress Cataloging-in-Publication Data

Names: Welch, Rosanne, author. | Lamphier, Peg A., author.

Title: Technical innovation in American history : an encyclopedia of science and technology / Rosanne Welch and Peg A. Lamphier, editors.

Description: Santa Barbara, California : ABC-CLIO, an Imprint of ABC-CLIO, LLC, 2019. | Includes bibliographical references.

Identifiers: LCCN 2018043489 (print) | LCCN 2018045557 (ebook) | ISBN 9781610690942 (ebook) | ISBN 9781610690935 (set) | ISBN 9781440847219 (volume 1) | ISBN 9781440847226 (volume 2) | ISBN 9781440847233 (volume 3)

Subjects: LCSH: Technological innovations—United States—History—Encyclopedias.

Classification: LCC T21 (ebook) | LCC T21 .T37 2019 (print) | DDC 609.73/03—dc23

LC record available at <https://lcn.loc.gov/2018043489>

ISBN: 978-1-61069-093-5 (set)
978-1-4408-4721-9 (vol. 1)
978-1-4408-4722-6 (vol. 2)
978-1-4408-4723-3 (vol. 3)
978-1-61069-094-2 (ebook)

23 22 21 20 19 1 2 3 4 5

This book is also available as an eBook.

ABC-CLIO

An Imprint of ABC-CLIO, LLC

ABC-CLIO, LLC

147 Castilian Drive

Santa Barbara, California 93117

www.abc-clio.com

This book is printed on acid-free paper 

Manufactured in the United States of America

Contents

VOLUME 1: COLONIAL AMERICA TO 1865

Introduction, xxi

Chronology, xxvii

Section 1: Colonial America and Enlightenment Science, 1

Overview, 1

American Philosophical Society, 8

Primary Document: Memorial of the American Philosophical Society Favoring an Exploration of the Alaskan Coast (1868), 10

Astronomical Almanacs, 11

Primary Document: Aphorisms from *Poor Richard's Almanack* (1732–1758), 13

Banneker, Benjamin (1731–1806), 13

Primary Document: Letter of Thomas Jefferson to Benjamin Banneker, Expressing Jefferson's Belief That Blacks Had Talents Equal to Other Races (1791), 14

Primary Document: Frontispiece of Benjamin Banneker's *Pennsylvania, Delaware, Maryland and Virginia Almanack and Ephemeris* (1792), 15

Bifocals, 16

Primary Document: Benjamin Franklin's Letter Describing His Invention of Bifocals (1725), 17

Bushnell, David (1740–c. 1824), 17

Primary Document: Engraving of David Bushnell's *American Turtle* (1775), 18

Colden, Jane (1724–1766), 19

Daylight Saving Time, 20

Extension Arm (Long Arm), 21

Fire Safety, 21

Flexible Catheter, 22

Food Production, Native American, 23

Franklin, Benjamin (1706–1790), 25

Primary Document: Letter of Benjamin Franklin Describing His Experiments with Electricity (c. 1750), 26

Franklin Stove, 27

Primary Document: Excerpt from Benjamin Franklin's *An Account of the New Invented Pennsylvanian Fire-Places* (1744), 28

Glass Harmonica (Armonica), 30

Primary Document: Excerpt of Benjamin Franklin's Letter to Father Giambatista Beccaria Describing the Glass Harmonica (1762), 32

Glover, Elizabeth (d. 1643), 32

Godfrey, Thomas (1704–1749), 33

Iron- and Silversmithing, 34

Kentucky Long Rifle, 35

Lightning Rod, 36

Primary Document: Frontispiece and Title Page of Benjamin Franklin’s *Experiments and Observations on Electricity* (1774), 37

Loom, 38

Primary Document: Excerpts from the Diary of Martha Ballard Describing Home Weaving (1787), 39

Lucas, Eliza (1722–1793), 40

Primary Document: Letter of Eliza Lucas to Her Father (1741), 41

Masters, Sybilla (c. 1675–1720), 42

Mather, Cotton (1663–1728), 43

Natural History, 44

Onesimus (fl. 1706–1716), 46

Peale, Charles Willson (1741–1827), 47

Primary Document: Letter of Charles Willson Peale to Thomas Jefferson Regarding New Agricultural Inventions and Innovations (1815), 48

Priestley, Joseph (1733–1804), 51

Rittenhouse, David (1732–1796), 52

Primary Document: Letter of Thomas Jefferson to David Rittenhouse (1778), 53

“Saugus Pot,” 54

Schooner, 55

Smallpox Inoculation, 56

Primary Document: George Washington’s Order for All Soldiers to Receive a Smallpox Inoculation (1778) and Letter of Edward Rowse to Thomas Jefferson Suggesting the Possibility of Vaccines for Other Diseases (1805), 58

Spinning Wheel, 59

Primary Document: An “Address to the Ladies” Urging American Women to Boycott British Goods (1767), 61

Street Lighting, 62

Swim Fins, 62

Three-Wheel Clock, 63

Primary Document: James Ferguson’s Description of Benjamin Franklin’s Three-Wheel Clock (1773), 64

Turtle Submarine, 65

Primary Document: Letter of David Bushnell to Thomas Jefferson Regarding Bushnell’s Experiments with Submarines (1787), 66

Whiton, David Erskine (1825–1904), 67

Winthrop, John (1714–1779), 68

Primary Document: John Winthrop Describes His Observation of the Planet Venus (1761), 69

Section 2: The New Republic and the Market Economy (1780–1820), 71

Overview, 71

Amphibious Steam Vehicle, 79

Primary Document: Image of an Amphibious Steam Vehicle (1834), 81

Apple Parers, 82

Primary Document: Apple Parer Patent Document Image (1836), 83

Babbitt, Sarah “Tabitha” (1779–1853), 84

Ballard, Martha (1735–1812), 84

Banjo Clock, 87

Blackwell, Elizabeth (1821–1910), 87

Primary Document: Excerpts from “Address on the Medical Education of Women” by Elizabeth and Emily Blackwell (1863), 89

Burr Truss Bridge, 91

Canals, 92

Canning Factory, 95

Charting the Gulf Stream, 96

Circular Saw, 97

Coffee Percolator, 98

- Cotton Gin, 99
- Cotton Sewing Thread, 101
- Dental Floss, 102
- Diffraction Grating, 103
- Erie Canal, 104
 - Primary Document: Letter of Robert Fulton to George Washington Urging Him to Support the Construction of Canals (1797), 106
- Evans, Oliver (1755–1819), 107
 - Primary Document: Letters from Oliver Evans to Thomas Jefferson (1804, 1808), 108
- Fire Hydrant, 109
 - Primary Document: Account of the Detroit Fire (1805), 110
- Fitch, John (1743–1798), 111
- Flatboat, 112
- Fulton, Robert (1765–1815), 114
- Gas Tungsten Arc Welding, 115
- Greene, Catharine Littlefield (1755–1814), 116
- High-Pressure Steam Engine, 117
- Interchangeable Parts, 118
- Internal Combustion Engine, 119
- Jefferson, Thomas (1743–1826), 121
- Lewis and Clark Expedition (1804–1806), 123
 - Primary Document: Excerpts from the Journal of the Lewis and Clark Expedition (1805, 1806), 126
- Lobster Trap, 127
- Lowell Mill System, 128
 - Primary Document: Description of the Life of a Mill Girl from the Lowell Offering (1845), 129
- Milling Machine, 130
- Morey, Samuel (1762–1843), 131
- Multitubular Boiler, 132
- National Road, 132
- Odometer, 135
- Patent and Copyright Statutes, 135
- Practical Ocean Navigation, 137
- Report on Manufactures* (1791), 138
- River Steamer, 139
- Rumford Fireplace, 141
- Rush, Benjamin (1746–1813), 142
 - Primary Document: Excerpt from the Medical Writings of Benjamin Rush (1805), 144
- Screw-Cutting Lathe, 145
- Slater, Samuel (1768–1835), 146
- Steam Engine, 148
- Steam Tractor, 149
- Steamboat, 150
 - Primary Document: Newspaper Announcement of Robert Fulton’s Steamboat (1807) and Charles Dickens’s Account of His Ride on an American Steamboat (1842), 153
- Submarine, 154
- Suspension Bridge, 155
- Swivel Chair, 157
- Thompson, Benjamin (Count Rumford) (1753–1814), 158
- Three-Piece Iron Plow, 159
 - Primary Document: Petition to Congress Asking for a Renewal of the Patent on Jethro Wood’s Cast-Iron Plow (1846), 160
- Vapor-Compression Refrigerator, 161
- Waltham-Lowell Textile System, 161
- Wheel Cipher, 162
 - Primary Document: Excerpts from Thomas Jefferson’s Notes on the Wheel Cipher (Undated), 163
- Whitney, Eli (1765–1825), 163
 - Primary Document: Letter of Eli Whitney to His Father Regarding the Ginning of Cotton (1793), 165

Section 3: Antebellum Industrialization and the Civil War (1820–1865), 167

Overview, 167

Adhesive Tape, 174

Agassiz, Louis (1807–1873), 175

Primary Document: Excerpt from the Journal of Louis Agassiz Describing a Trip to the United States (1846), 176

Anesthesia, 178

Ball Bearings and Babbitt Metal, 179

Best Friend Steam Engine, 181

Breast Pump, 182

Brown Truss, 182

Burglar Alarm, 183

Calliope (Steam Organ), 183

Cannon, Double-Barrel, 185

Primary Document: Excerpt from the Memoirs of Former Confederate General Edward Porter Alexander on “Artillery Hell” at Antietam (1907), 186

Civil War Medicine (1861–1865), 186

Primary Document: Report of Medical Director Robert Murray on Union Casualties Suffered at the Battle of Shiloh (1862), 188

Civil War Nursing, 190

Primary Document: Clara Barton’s Poem “The Women Who Went to the Field” (1892), 192

Clipper Ship, 194

Primary Document: Excerpts from the Journal of Alexander Van Valen Describing His Journey to California via Clipper Ship (1849), 196

Clothespin, 196

Coal-Mining Technologies, 197

Coil Magnet/Electromagnet, 199

Colgate, William (1783–1857), 200

Colored Female Free Produce Society, 201

Colt, Samuel (1814–1862), 202

Colt Revolver, 203

Columbiad Cannon, 204

Combine Harvester, 205

Compact Iron Stove, 207

Conestoga Wagon, 208

Primary Document: Excerpt from John G. Abbott’s Recollections of Traveling to California by Wagon Train (1852), 210

Corn Sheller, 211

Corset, 211

Coston, Martha (1826–1904), 213

Cowboy Hat (Stetson), 213

Crumpler, Rebecca (1831–1895), 214

Cylinder Pin Tumbler Lock, 216

Dahlgren Gun, 216

Deere, John (1804–1886) and Deere and Company, 217

Dental Chair, 219

Detachable Collar, 219

Dix, Dorothea (1802–1887), 220

Dustpan, 221

Eggbeater, 222

Electric Doorbell, 223

Electric Stove, 223

Electric Street Railway, 223

Elevator Safety Brake, 224

Equatorial Sextant, 225

Field, Cyrus West (1819–1892), 226

Fire Alarm Call Box, 227

Floating Dry Dock (1849), 228

Primary Document: Excerpt from Abraham Lincoln’s Patent Application for the Floating Dry Dock (1849), 229

Gas Well, 230

Gold-Mining Technologies, 231

Goodyear, Charles (1800–1860), 232

- Grain Elevator, 233
- Gridiron for Cooking, 234
- Hand-Cranked Ice Cream Maker, 234
- Health Reform, 235
- Henry, Joseph (1797–1878), 237
- Hoop Skirt, 238
- Horse-Drawn Streetcar, 239
 - Primary Document: Image of a Horse-Drawn Streetcar (c. 1920), 240
- Hospital Transport Service, Women’s Department, 240
- Howe, Elias (1819–1867), 241
- Howe Truss, 242
- Interchangeable Gun Parts, 243
- Inverted Microscope, 244
- Jervis, John B. (1795–1885), 245
- Land Mines, 245
- Long, Crawford Williamson (1815–1878), 246
- Machine/Gatling Gun, 247
- Mason Jar, 249
- Maynard, Edward (1813–1891), 249
- Maynard Carbine, 250
- McCormick, Cyrus (1809–1884), 252
 - Primary Document: Letter of Robert E. Lee to Cyrus McCormick Regarding the Curriculum at Washington College (1865), 253
- Mechanical Reaper, 254
- Merrick, Solymon (1806–1852), 255
- Military Technology (Civil War), 255
- Mitchell, Maria (1818–1889), 258
- Morse, Samuel F. B. (1791–1872), 260
- Morse Code, 261
- National Academy of Sciences (NAS), 262
- Nightingale Plan, 263
- North, Simeon (1765–1852), 264
- Omnibus System, 265
- Papermaking Machine, 266
- Pencil Eraser, 267
- Pepper (and Salt) Shaker, 267
- Perkins, Jacob (1766–1849), 267
- Platform Scale, 268
- Polished Steel Plow, 269
- Printing, 269
- Printing Telegraph, 271
- Pullman, George Mortimer (1831–1897), 273
- Railroad T-Rail and Tie, 273
- Railroads, 274
 - Primary Document: Pacific Railway Act (1862), 276
- Ratchet Wrench, 279
- Relay, 280
- Repeating Rifle, 280
- Roller Skates, 282
- Rotary Hook (for Sewing Machines), 283
- Rucker Ambulance, 283
- Safety Pin, 284
- Sewing Machine, Automated, 284
- Sewing Pattern, 286
- Solar Compass, 287
- Spar Torpedo, 288
- Steam Locomotive, 288
- Steam Shovel, 291
- Stevens, Robert Livingston (1787–1856), 292
- Strauss, Levi (1829–1902), 294
- Telegraph, 294
 - Primary Document: Act Authorizing Construction of a Transcontinental Telegraph (1855), 297
- Ten-Hour Movement, 297
 - Primary Document: Excerpt from the Preamble and Constitution of the Lowell Female Labor Reform Association (1846), 298
- Toothpaste, 299

Torpedo, 301
 Transatlantic Cable, 302
 Transverse Shuttle, 303
 Twine Knotter, 304
 Twist Drill, 304
 United States Capitol Building, Construction of, 304
 U.S. Sanitary Commission (USSC), 306

Vulcanization, 307
 Walker, Mary (1832–1919), 308
 Western Union Telegraph Company, 310
 Zipper, 311

Bibliography: Colonial America to 1865, 313
Index, 317

VOLUME 2: RECONSTRUCTION THROUGH WORLD WAR II

Section 1: The Rise of Industrialism, Reconstruction, and the Gilded Age (1866–1900), 1

Overview, 1

Abbe, Cleveland (1838–1916), 7

AC Generator and Transformer, 9

Primary Document: American Institute of
 Electrical Engineers (AIEE) Member
 Biography for William Stanley (1934), 10

AC Induction Motor, 10

Primary Document: Nikola Tesla's Patent for an
 AC Induction Motor (1896), 11

Adding Machine with Keys, 14

Amalgamated Clothing Workers of America
 (ACWA), 14

American Telephone and Telegraph Company
 (AT&T), 16

Asphalt, 17

Aspirin, 18

Barbed Wire, 19

Primary Document: Excerpts from an Article on
 Joseph F. Glidden and the Barb-Wire
 Industry (1884), 21

Batteries, 23

Bee Smoker, 24

Primary Document: Excerpt on the Use of a Bee
 Smoker from Moses Quinby's *Mysteries of
 Bee-Keeping Explained* (1853), 24

Bell, Alexander Graham (1847–1922), 26

Primary Document: Letter of Alexander Graham
 Bell to His Parents Describing His Idea for
 the Telephone (1874), 27

Berliner, Emile (1851–1929), 29

Brooklyn Bridge, 30

Camera, 31

Can Opener, 33

Carnegie, Andrew (1836–1919), 34

Carnegie Steel Mill, 35

Primary Document: Correspondence of Andrew
 Carnegie and Henry Clay Frick Regarding
 the Homestead Strike (1892), 37

Carpet Sweeper, 38

Carver, George Washington (1861–1943), 38

Primary Document: George Washington Carver
 Addresses Congress (1921), 41

Cash Register, 42

Celluloid, 42

Coca-Cola, 43

Cotton Candy Machine, 45

Crayons, 45

Curling Iron, 47

Diner (Horse-Drawn), 47

Dishwashing Machine, 48

Dow Chemical Company, 49

- du Pont, Pierre (1870–1954), 50
- DuPont Company, 52
- Duprey, Ana Roqué de (1853–1933), 54
- Duryea, Charles (1861–1938) and Frank (1869–1967), 54
- Earmuffs, 55
- Eastman, George (1854–1932), 56
- Eastman Kodak Company, 56
- Edison, Thomas (1847–1931), 57
- Electric Iron, 59
- Electric Lightbulb, 60
- Electricity, War of the Currents, 61
- Electrification, Urban, 63
- Escalator, 65
- Ferris Wheel, 66
 - Primary Document: Telegrams between Luther Rice and George Ferris Following the Successful Test of the Ferris Wheel (1893), 68
- Folding Cabinet Bed, 68
 - Primary Document: Patent for Folding Cabinet Bed (1885), 69
- Food Preservation, 70
- Fountain Pen, 71
- Frasch Process, 72
- Gas Transmission, 73
- General Electric, 74
- Goodrich, B. F. (1841–1888), 75
- Goodyear, Charles, Jr. (1833–1896), 76
- Hallidie, Andrew Smith (1836–1900), 76
- Harvard Computers, 77
 - Primary Document: Undated Photo of the Harvard Computers, 79
- Haynes, Elwood (1857–1925), 79
- Heyl, Henry (1842–1919), 80
- Ice Cream Soda, 81
- Inman, George (1895–1972), 82
- Iron Ship with Revolving Turret, 83
- Ironing Board, 83
- Jeans, 84
- Jockstrap, 86
- Jones, Amanda T. (1835–1914), 86
 - Primary Document: “The Soldier’s Mother” by Amanda T. Jones (1867), 87
- Kellogg, William Keith (1860–1951), 88
- Kelly, William (1811–1888), 89
- Kier, Samuel (1813–1874), 90
- Kinematoscope, 91
- Knight, Margaret (1838–1914), 91
- Lady Stitchers’ Union, 92
- Lawn Mower, Reel-Type, 93
- Lennox, David (1855–1947), 93
- Linotype Machine, 94
- Margarine, 95
- Matchbook Matches, 96
- Matzeliger, Jan Ernst (1852–1889), 96
- Maxim, Hudson (1853–1927), 97
- Metal Detector, 97
- Metal Electrode Weld, 98
- Metal Windmill, 99
- Military Technology (Post–Civil War through World War I), 100
- Motion Picture Camera, 102
- National Consumers League, 104
- National Institutes of Health (NIH), 105
- Niagara Falls Power Plant, 106
 - Primary Document: Excerpt from Nikola Tesla’s Commemoration Address for the Niagara Falls Power Plant (1897), 108

Office Technology (Pre–World War II), 112

Paper Bag, 114

Paper Clip, 114

Phonograph, 115

Primary Document: Roll Call of Companies at
the Phonograph Convention in Chicago
(1890), 119

Photographic Film, 120

Pipe Wrench, 121

Player Piano, 121

Portland Cement Mortar, 122

Punch Card Tabulator, 123

Quadruplex Telegraph, 124

Railroad Refrigerator Car, 125

Railroad Sleeping Car and Pullman Car, 126

Railroad Switch Systems, 127

Richards, Ellen Swallow (1842–1911), 128

Roebing, Emily (1843–1903), 129

Primary Document: Photograph of the Promenade
on the Brooklyn Bridge (1899), 131

Roebing, John (1806–1869), 131

Roll Film, 133

Roller Coaster, 133

Rotary Washing Machine, 134

Rowing Machine, 135

Saccharine, 135

Silo, 137

Skyscraper, 138

Soda Fountain, 140

Spork, 141

Steel Arched Bridge, 142

Stethoscope, Binaural, 143

Stockyards, 144

Primary Document: Photograph of Chicago’s
Union Stock Yards (1907), 145

Tape Measure, 146

Taylor, Frederick (1856–1915), 146

Tesla, Nikola (1856–1943), 147

Ticker Tape, 149

Tom Thumb Locomotive, 150

Primary Document: John Latrobe’s Description
of the *Tom Thumb* Locomotive (1830), 150

Track-Type Tractor, 152

Transcontinental Railroad, 153

Twine Self-Binding Harvester, 155

Typewriter and QWERTY, 155

Velocipede, 156

Vending Machine, 157

Vibrator, 158

Water Heater, 159

Westinghouse Air Brake, 160

World’s Fairs, 161

Wright, Wilbur (1867–1912) and Orville
(1871–1948), 164

Primary Document: Entry from Orville Wright’s
Diary of December 17, 1903, 166

Yerkes Observatory, 166

Section 2: The Progressive Era and the Roaring Twenties (1900–1929), 169

Overview, 169

Aerosol Spray Can, 176

Airplane, 176

Anderson, Mary (1866–1953), 179

Assembly Line, 179

Primary Document: Excerpt from Henry Ford’s
“The First Assembly Line” (1913), 181

Automobile Technologies (Pre–World War II), 181

Bakelite, 183

Band-Aid, 185

Bell Telephone Laboratories, 185

- Binney & Smith Inc., 186
- Birdseye, Clarence (1886–1956), 187
- Blender, 188
- Blodgett, Katherine (1898–1979), 188
- Boeing, William E. (1881–1956), 189
- Bottle-Making Machine, 190
- Bread Slicer and Wrapping Machine, 191
- Bryant, Alice (1862–1942), 192
- Cannon, Annie Jump (1863–1941), 192
- Carothers, Wallace (1896–1937), 194
- Christmas Tree Lights, 194
- Chuck Wagon, 195
- de Forest, Lee (1873–1961), 196
- Dickelman, Elizabeth (dates unknown), 197
- Dickerson, Mary Cynthia (1866–1923), 197
- Drew, Charles (1904–1950), 198
- Ductile Tungsten, 199
- Einstein, Albert (1879–1955), 199
- Empire State Building, 201
- Ford, Henry (1863–1947), 202
- Freon, 204
- Galvin, Paul Vincent (1895–1959), 205
- General Motors (GM), 206
- Gilbreth, Lillian (1878–1972), 208
- Gramophone/Victrola, 208
- Gumball Machine, 210
- Hewitt, Peter C. (1861–1921), 210
- Hoosier Cabinet, 212
- Hydroelectric Power, 212
- Jacob, Mary Phelps (1891–1970), 214
- Kettering, Charles F. (1876–1958), 215
- Lie Detector, 216
- Life Savers Candy, 217
- Marsh, Albert L. (1877–1944), 217
- McKnight, William L. (1887–1978), 218
- Midgley, Thomas (1889–1944), 219
- Morgan, Garrett (1877–1963), 220
- Motorcycle (Pre–World War II), 221
- National Advisory Committee for Aeronautics (NACA), 223
- Noether, Amalie Emmy (1882–1935), 224
- Olds, Ransom Eli (1864–1950), 225
- Panama Canal, 225
 - Primary Document: Excerpt from President Theodore Roosevelt’s Message to Congress After Returning from the Canal Zone in Panama (1906), 228
- Pennington, Mary Engle (1872–1952), 232
- Petroleum Industry (Pre–World War II), 233
- Pop-Up Toaster, 234
- Pushpin, 235
- Radio, 236
 - Primary Document: “Radio’s Real Uses” by E. E. Free, Science Editor for *The Forum* (1926), 239
- Rocky Mountain Laboratories, 240
- Safety Razor, 240
- Scotch Tape, 241
- Subway System of New York City, 242
- Talking Movies, 243
- Traffic Light, Electric, 245
- Triode Tube, 246
- Turbine Engine, Gas Powered, 247
- Washing Machine, Electric, 247
- Welding, Alternating Current, 248
- Welding, Automatic, 249

Section 3: The Great Depression and World War II (1930–1945), 251

Overview, 251

Alaska Highway, 257

Primary Document: Excerpt from Ruth Gruber’s Study of Highway Routes to Alaska (1941), 259

Atomic Bombs/Nuclear Weapons, 260

Avenger Field, 261

Primary Document: Letters of Mary Anna Martin Wyall, a Pilot Trainee at Avenger Airfield (1944), 262

B-17 Flying Fortress, 263

Big Science, 264

Blood Transfusion, 265

Bradberry, Henrietta (1903–1979), 266

Calutron Girls, 267

Clarke, Edith (1883–1959), 268

Curtiss-Wright Aeronautical Engineering Cadettes, 269

D Rations, 270

Electric Guitar, 270

Fermi, Enrico (1901–1954), 271

FM Radio, 272

Freeze-Dried Food, 273

Garbage Disposal, 273

Gas Mask, 274

Golden Gate Bridge, 274

Primary Document: Letter of Charles Ellis to the *San Francisco Chronicle* Regarding the Golden Gate Bridge (1930), 275

Helicopter, 276

Hoover Dam, 277

Primary Document: President Franklin D. Roosevelt’s Speech at the Dedication of Hoover Dam (1935), 280

Hydrogen Bomb, 283

Hydroponics, 284

International Ladies’ Garment Workers’ Union (ILGWU), 285

Primary Document: “The Uprising of the 20,000,” 286

Interstate Highway System, 287

Primary Document: Excerpt from the Federal-Aid Highway Act (1956), 289

Lamarr, Hedy (1914–2000), 290

Primary Document: Patent for Hedy Lamarr’s Frequency-Hopping System (1942), 292

Lange, Dorothea (1895–1965), 292

Lend-Lease Program (1941–1945), 293

Liberty Ships, 294

M&M’s, 295

M4 Sherman Tank, 295

Manhattan Project, 296

Mead, Margaret (1901–1978), 297

Microwave Oven, 299

Military Technology (World War II), 299

MIT Radiation Laboratory, 301

Neoprene, 302

Oppenheimer, J. Robert (1904–1967), 303

Paul, Les (1915–2009), 304

Penicillin, 306

pH Meter, 307

Photocopier, 307

Pinball and Arcade Games, 308

Plastic Wrap, 309

Radar, 309

Refrigerator, 310

Richter Scale, 311

Rocketry (Pre–Space Age), 311

Rosie the Riveter, 313

Primary Document: Excerpt from Interview with Maria Isabel Solis (2003), 315
 Schwinger, Julian (1918–1994), 316
 Semple, Ellen Churchill (1863–1932), 317
 SONAR, 318
 Submarine Technology, 319
 Tampon, 320
 Tea Bag, 321
 Telephone, 322

Television, 325
 Tennessee Valley Authority Electricity Project (TVA), 328
 Thomas, Vivien Theodore (1910–1985), 329
 Tizard Mission, 331
 Women's Airforce Service Pilots (WASPs), 331
 Wu, Chien-Shiung (1912–1997), 333

Bibliography: Reconstruction through World War II, 335
Index, 339

VOLUME 3: THE COLD WAR TO THE PRESENT

Section 1: The Cold War (1946–1979), 1

Overview, 1
 911 Emergency System, 8
 Agent Orange, 9
 “Air” Athletic Shoes, 11
 Antiballistic Missiles (ABMs), 11
 Antibiotic, 13
 Apollo Project, 14
 ARPANET, 16
 Aspartame, 18
 Association for Women in Mathematics (AWM), 19
 Atari, 20
 Automotive Technologies (Post–World War II), 22
 Baer, Ralph (1922–2014), 24
 Primary Document: Excerpt from Ralph Baer's Four-Page Paper Describing His Plans for Simple Video Games (1966), 25
 Bar Code Scanner, 25
 Benerito, Ruth Rogan (1916–2013), 27
 Biodiesel, 27
 Primary Document: Statement of Anne Steckel, the Vice President of Federal Affairs of the National Biodiesel Board, to the Senate Committee on Environment and Public Works (2016), 29

Birth Control Pill, 31
 Bomb Disposal Robots/Units, 33
 Brill, Yvonne Madalaine Claeys (1924–2013), 34
 Primary Document: Yvonne Brill's Patent for New Jet Propulsion Technology (1974), 35
 Brown, Marie Van Brittan (1922–1999), 35
 Bulletproof Vest/Kevlar, 36
 Carson, Rachel (1907–1964), 36
 Chlorofluorocarbons (CFCs), 38
 Climate Change, 39
 CO₂ Welding, 41
 Commodore 64, 42
 Comsat/Intelsat, 42
Curanderas, 43
 Dark Matter Science, 45
 Dolby Laboratories, 47
 Drones, 48
 Electric Car, 49
 Primary Document: Article from the energy.gov Web Site on Electric Cars (2014), 50
 Enders, John Franklin (1897–1985), 54
 Engelbart, Douglas (1925–2013), 55

- ENIAC and the “ENIAC Girls,” 55
- Fortran, 56
- Fuller, Richard Buckminster (1895–1983), 57
 - Primary Document: Drawing of R. Buckminster Fuller’s Geodesic Dome (c. 1933), 58
- Global Positioning System (GPS), 59
- Goeppert-Mayer, Maria (1906–1972), 60
- Graham, Bette (1924–1980), 61
- Hamilton, Margaret (1936–), 62
- Haynes, Martha Euphemia Lofton (1890–1980), 63
- Hopper, Grace (1906–1992), 65
- Hydraulic Fracturing (“Fracking”), 66
- Hydrogen Energy, 67
- IBM 360 Computer, 68
- In Vitro Fertilization (IVF), 70
- Integrated Circuit, 70
- Intel Corporation, 71
- Jackson, Mary Winston (1921–2005), 72
- Jet Propulsion Laboratory (JPL), 74
- Johnson, Katherine Goble (1918–), 75
- Kilby, Jack (1923–2005), 76
- Kwilek, Stephanie Louise (1923–2014), 77
- Lacks, Henrietta (1920–1951), 78
- Land, Edwin H. (1909–1991), 79
- Lasers, 80
- LED Lights, 81
- Liquefied Natural Gas (LNG) Carrier, 82
- Liskov, Barbara (1939–), 82
- M16 Rifle, 83
- Magnetic Resonance Imaging (MRI), 84
- MASER, 85
- McClintock, Barbara (1902–1992), 86
- Mercury 13, 88
- Military-Industrial Complex, 88
- Minsky, Marvin (1927–2016), 90
- Moog, Robert (1934–2005), 91
- Morgan, Mary Sherman (1921–2004), 92
- Nanotechnology, 93
- Napalm, 94
- National Aeronautics and Space Administration (NASA), 94
 - Primary Document: Letter of President Dwight Eisenhower to Keith Glennan, Retiring Administrator for NASA (1960), 98
- National Science Foundation (NSF), 98
- Noyce, Robert (1927–1990), 99
 - Primary Document: Personal Interview with Robert Noyce for the IEEE History Center (1975), 100
- Nuclear and Radiation Accidents, 102
- Ochoa, Ellen (1958–), 105
- Orshansky, Mollie (1915–2006), 106
- Packet Switching, 107
- Particle Accelerator, 108
 - Primary Document: Press Release Issued by CERN, the European Organization for Nuclear Research (2012), 109
- Pauling, Linus “Carl” (1901–1994), 110
- Permanent Press Fabric, 111
- Petroleum Industry (Post–World War II), 112
- Plasma Arc Welding, 114
- Plastics, 115
- Polaroids, 117
- Polio Vaccine, 118
- Pong*, 119
- Portable Transistor Radio, 120
- Rocket Girls of JPL, 121

- Primary Document: Press Release Announcing Eleanor F. Helin's Naming to the Women in Science and Technology International (WITI) Hall of Fame (1998), 122
- Rogallo, Francis Melvin (1912–2009), 123
- Sabin, Albert B. (1906–1993), 124
- Salk, Jonas (1914–1995), 125
- Satellites and Space Probes, 126
- Sherman, Patsy O'Connell (1930–2008), 127
- Shippingport Atomic Power Station, 128
- Silent Spring* (1962), 129
- Silicon Valley, 130
- Single-Chip Microprocessor, 132
- Skylab, 133
- Skywalker Ranch, 134
- Smallpox, Eradication of, 135
- Smoke Detector, 136
- Primary Document: Chris P. Borreson's Account of the Iroquois Theater Fire (1904), 137
- Space Science and Technology, 137
- Primary Document: Account of Astronaut David Alexander Wolf Voting in Space (1997), 138
- Stealth Technologies, 138
- Superconductivity, 140
- Taussig, Helen (1898–1986), 141
- Telephone Switching, Computerized, 143
- Thomas, Valerie (1943–), 144
- Touch-Tone Phones, 145
- Trans-Alaska Pipeline, 145
- Primary Document: Bill to Reform the Trans-Alaska Pipeline System Authorization Act (1989), 146
- Transistor Radio, 148
- TV Dinner, 149
- Unimate/Industrial Robot, 150
- Universal Automatic Computer (UNIVAC), 150
- Vaccines, 151
- Vaughan, Dorothy (1910–2008), 153
- Vocoder, 155
- Voyager Spacecraft, 156
- Wise, Brownie (1913–1992), 157
- Xerox Corporation, 158
- Primary Document: Patent for Xerography (1956), 159
- Yalow, Rosalyn Sussman (1921–2011), 160
- Section 2: The Post–Cold War Era (1980–1999), 163**
- Overview*, 163
- AIDS Research, 171
- Primary Document: Introduction to the AIDS Archive by Former Surgeon General C. Everett Koop, 173
- Apple, 177
- Apple II, 179
- Artificial Heart, 180
- Artificial Intelligence (AI), 181
- Berners-Lee, Tim (1955–), 184
- Boston Tunnel, 185
- CD and DVD, 186
- CD-ROM, 188
- Computer/Information Technology, 189
- Cray, Seymour (1925–1996), 191
- Dell, Michael “Saul” (1965–), 192
- Digital Photography, 193
- Primary Document: Excerpt from the Patent for Kodak's Digital Camera (1978), 195
- Elion, Gertrude (1918–1999), 195
- Floppy Disk, 197
- Fossey, Dian (1932–1985), 198
- Gates, Bill (1955–), 199

Genetic Engineering, 201
 Gosling, James (1955–), 204
 IBM Personal Computer, 205
 Infant Formula, 206
 Insulin Pump, 207
 Internet, 208
 Jobs, Steve (1955–2011), 209
 Kare, Susan (1954–), 213
 Laser Cataract Surgery Device, 213
 Metcalfe, Robert (1946–), 214
 Microchip, 215
 Microsoft, 217
 Mobile Phone, 218
 Nuclear Energy/Nuclear Power Plants, 219
 Open-Source Software, 221
 Perlman, Radia (1951–), 222
 Personal Computer (PC), 223
 Ride, Sally (1951–2012), 224
 Ritchie, Dennis (1941–2011), 226
 Primary Document: Abstract for “The Development
 of the C Language” by Dennis Ritchie
 (1993), 227
 Robotic Surgery, 229
 Primary Document: Letter from Elizabeth A.
 Kage, Acting District Director of the FDA, to
 Gary S. Guthart, President of Intuitive
 Surgical Inc., on the Regulation of Robotic
 Surgery (2013), 230
 Satellite Radio, 232
 Self-Driving Cars, 233
 SEMATECH, 234
 Solar Energy, 235
 Space Shuttle, 237
 Strategic Defense Initiative (SDI), 239

Sustainable Agriculture, 240
 Wind Energy, 242
 Wozniak, Steve (1950–), 244

Section 3: The New Millennium (2000–Present), 247

Overview, 247
 Airplane Deicer, 254
 Amazon Web Services, 255
 Amazon.com, 256
 Artificial Memories, 258
 Bashen, Janet (1957–), 259
 Birth Control Patch, 260
 Blizzard Entertainment, 260
 Cancer Research, 261
 Cassini Saturn Mission, 262
 Drake Equation, 264
 e-Book and e-Reader, 264
 e-Sports, 267
 Facebook, 268
 Gene Patenting, 270
 Genetically Modified Foods, 271
 Google, 274
 Google Earth, 275
 Grandin, Temple (1947–), 276
 Hawking, Stephen (1942–2018), 277
 Hubble Space Telescope, 278
 Human Genome Project, 279
 Hybrid Vehicles, 281
 Hypertext, 283
 International Space Station, 283
 Intraocular Contact Lens, 285
 iPod, 286

- Java, 287
 - Primary Document: Interview with James Gosling, the Creator of Java (2001), 288
- Jemison, Mae (1956–), 290
- Joystick/Flight Simulator, 291
- Kurzweil, Ray (1948–), 291
- Linux, 292
- Maker Faire, 293
- March for Science, 295
- Mars Rover Series, 295
- MIDI (Musical Instrument Digital Interface), 297
- Moore, Ann (1934–), 298
- MP3, 298
- Negroponte, Nicholas (1943–), 299
- Netscape, 300
- Nye, Bill (1955–), 302
- One Laptop per Child, 302
- PayPal, 303
- PGP Encryption, 303
- Quantum Science, 304
- RFID Labels, 305
- RU-486/Plan B, 307
- Science Friday*, 308
- SETI (Search for Extraterrestrial Intelligence), 308
- Smartphone and 3G Network, 311
- Tarter, Jill (1944–), 312
- Thompson, Ken (1943–), 313
 - Primary Document: Interview with Ken Thompson, Inventor of the UNIX System (2011), 314
- 3-D Printing, 316
- TOR (The Onion Router), 318
- Torvalds, Linus (1969–), 318
- Tyson, Neil deGrasse (1958–), 319
- Video Game, 321
- Video Streaming Services, 323
- Virtual Reality (VR), 323
- Wang, An (1920–1990), 325
- Williams, Roberta (1953–) and Ken (1954–), 327
- Wireless Communication, 328
- YouTube, 330
- Bibliography: The Cold War to the Present*, 331
- Editors and Contributors*, 335
- Index*, 345

1. The Rise of Industrialism, Reconstruction, and the Gilded Age (1866–1900)

OVERVIEW

During the Gilded Age, the U.S. Patent Office granted a record number of patents, more than any previous time in American history. The era forever changed nearly every aspect of American life, with innovations influencing everything from the mundane to the extraordinary. The early part of this era, commonly referred to as the Industrial Revolution because machines increasingly began to replace the work of human hands, spanned the 1830s through the 1890s. The defining issues of the industrialization of the United States were the development of industries and the evolution of single-ownership businesses and partnerships into corporations, with an economic shift away from rural, agricultural lifestyles as a way to make a living and toward seeing big business and industry as the likeliest pathway to economic independence. Taking its cue from the United Kingdom, America experienced a boom in industry that also resulted in population growth as in no other era. The social, political, and economic landscape evolved, morphing into a process that in some ways continues to this day. Marked by an explosion of technological innovation most notable in communications and transportation, the era was fraught with complications, hardship, and wonder. Despite the tumult of a country adjusting to life during and after Civil War in the 1860s, rather than hindering its continued course of technological innovation and its advances, it encouraged the country not only to continue but also to thrive throughout the war and into Reconstruction and the Gilded Age aptly named by Mark Twain, an author whose work harkened back to nostalgia for rural life.

Among the dynamics of post-Reconstruction America, industrial production began to be controlled by a relative few. One of those industrialists was Scottish immigrant, pacifist, and philanthropist Andrew Carnegie. His Carnegie Steel Mill realized a fortune in steel production while battling labor disputes during the 1890s with paid mercenaries, which led to loss of life. Ultimately, Carnegie's voice would be among other early voices challenging the Gilded Age ideas of displaying wealth and conspicuous consumption. Believing in the value of education, he would give away much of his wealth, demonstrated in the tremendous number of libraries and universities that he helped found with his fortune.

The most important manufacturing centers of America by the 1880s were located on the East Coast. Newark and Paterson, New Jersey, housed prominent textile factories in the world of silk, ribbons, cloth, and thread. Machines utilized the power of steam in engines and turbines on land while American ingenuity developed an efficient system of transport at sea with the sleek design of the clipper ships. With increased demand for goods and services, the demand for steel, iron, and oil catapulted manufacturing on American soil into action. One of the key innovations of the era was the Bessemer converter fueling the steel industry by converting iron into steel. Carnegie's would be the first steel company to utilize the converter. During the 1850s, petroleum discoveries in the hills of Pennsylvania and New York revealed that once oil was refined, it could be used for illuminating lamps on steamships and railroads. Also, by the 1880s, the building industry began erecting skyscrapers.

In general, development of cities was propelled by the wealthy, and transportation was an important

component. Powerful financiers and industrialists of the era provided capital, including J. Pierpont Morgan (1837–1913) and John Jacob Astor IV (1864–1912), himself an inventor and considered the wealthiest man of the era. John D. Rockefeller exemplified the era known as the Gilded Age with his profound wealth. He bought his way through competing oil companies, and he manipulated employees, competitors, business partners, and the public to create and maintain his oil monopoly, Standard Oil. Some historians define Rockefeller as an astute (and sometimes lucky) businessman who created an important American enterprise. Still others reasoned that Rockefeller's collusions with the railroads proved important business decisions, though they exemplified Rockefeller's greed.

The years following the end of Reconstruction heralded the Gilded Age (1878–1899); its name was taken from the title of a Mark Twain novel describing the culture of political corruption and materialistic excess he saw in 1870s America. As the business landscape in the United States continued to change, the landscapes of its cities shifted as well. Skyscrapers dotted the skyline of Chicago by 1884, utilizing steel in their construction to offset the losses resulting from the Chicago Fire of 1871. The completion of the world's first steel suspension bridge, the Brooklyn Bridge, in 1883, connected New York City's Manhattan Island to Brooklyn, furthering America's rise as an industrial force.

The social impact crossed a broad spectrum of social repercussions as well as benefits. Among them were increased goods, services, and jobs. This generated taxes going into city, state, and federal coffers. Larger consequences appeared in damages to the environment and exploitation of its men, women, and child workers, widening the gaps between classes. For workers, long hours, low chances for advancement, small wages, and lack of safety protocols on the job created untold hardship. With the rise of industry came examinations by newspaper organizations responding to managers' exploitation of employees. Muckrakers exposed, through journalistic investigation, the inequities of exploitation by corrupt corporate and political entities. Government regulation and unionization efforts contributed to controlling the negative impact of industrialization.

Reconstructing after the Civil War

The Civil War furthered the already rapid rise of industry, notably in the steel industry, but the amplified demand for supplies—namely munitions and food along with transport for troops—also contributed to an increased demand for railroads. Commercially canned food proved safe and easier to transport, supplying the Union Army more efficiently than the Confederate Army as the northern United States had already had a burgeoning factory system in place before the war. Set against a backdrop of a divided country and its subsequent attempts at reunification, the periods following the American Civil War (1861–1865), referred to as Reconstruction (1866–1877), were socially fraught with conflict and adjustment. Scholars wrestled with the impact of Reconstruction for generations. With the defeat of the agrarian South (which had traditionally blocked laws aimed at promoting industrialization), the North turned its sight toward Reconstruction. A cheap supply of immigrant labor willing to work in factories in the North for bare subsistence wages provided an easily accessible and abundant supply of natural resources, especially coal and iron ore, to consumers. Later on, government support for industry with protective tariffs, loans, and subsidies for internal improvements and transportation projects all contributed to the corporate culture, the massive profits being acquired largely by capitalists. U.S. industrialists freely adapted and adopted technology from England. At this time, inventors and innovators relied upon investors and the patronage of the wealthy few to support the work of research and development.

Mills, breweries, and factories relied upon steam-powered engines by the 1880s. With the introduction of steam engines, the transport time for goods and services increased a hundredfold. This redefined what it meant to be wealthy for a limited few Americans. Rather than measure financial worth in terms of acreage, wealth was now defined in terms of dollars and how corporate entities efficiently utilized a labor force. Before the Industrial Revolution, power beyond the corporal was limited to wind and water. New sources of power in coal and gas reduced the amount of labor need to effectively complete jobs. Horsepower for generations had supplied the transport needs of a

growing population. A new use for the steam engine's mechanical power included the first oil well dug in Titusville, Pennsylvania, in 1859.

Bridging the Continent

The Transcontinental Railroad was the first American railway system connecting the eastern and western halves of the United States. Considered the most extraordinary enterprise ever undertaken in the 19th century, President Lincoln endorsed the Transcontinental Railroad finally authorized by Congress in 1862. The Pacific Railroad Act charged investors from Sacramento, California, to form the Central Pacific Railroad Company and establish tracks eastward, and the Union Pacific Railroad Company laid railroad tracks heading westward. Both were tasked to complete the enormous undertaking in the spirit of a competitive race, with the winner receiving a monetary bonus—though this bonus was not shared with the largely Chinese and Irish immigrants who provided most of the actual labor. Also, East pitted against West in competition resulted in hastily laid track that had to be relaid later as mounting accidents revealed the faulty workmanship. Completed in 1869, the project greatly influenced the transport of people, goods, and services and had the potential to reunite a divided country recovering from the Civil War.

Also in 1869, a telegraph sent from Promontory Point, Utah, across America announced the completion of the Transcontinental Railroad. The impact of the final golden spike driven into the last railroad tie reverberated throughout the country. The implementation of refrigerator cars by J. B. Sutherland allowed for transport of food at greater distances. Cattle shipments from the open ranges of the American West to the East Coast began in 1870. A number of railway systems had appeared throughout the United States, but none came close to connecting the East and West Coasts like the Transcontinental did. This affected not only food and cattle transport but also travel. Technological advances that followed included the railroad signal, air brake, and switch system by George Westinghouse, along with the sleeping car, which added comfort on passenger trains, furthering the success of the railroad system.

Not without consequences, the rapid expansion of the Transcontinental across thousands of acres of land took a heavy toll upon not only Native American populations but immigrants as well. While Native Americans continued to struggle with losses from broken treaties and continued encroachment by European expansion into Native territories, Chinese immigrants to California during the Gold Rush had discovered a place for their industry in building the historic Transcontinental Railroad, often under harsh conditions. But they faced legal discrimination and racism once the project was completed.

As technological advances increased in the eastern United States, industry in the American South increased post-Reconstruction. Although not on the same scale as in the North, and still recovering from the effects of life under wartime conditions, railroads, iron, and steel industries along with textile manufacturing had begun in the Southern regions due to low taxes and a labor force of largely female heads of households willing to accept subsistence wages. Often, these families uprooted themselves and moved to mill towns where employment advantages outweighed the post-Civil War devastation to family farms. Although this created jobs for households that were often without men, it kept these households dependent within the confines of the mill town system of high credit rates, long working hours and debt to factory owners, who very often were funded with Northern money.

The Southern factory system offered white households some semblance of a living, but for post-Civil War freedwomen and men, it remained a closed door except for the unskilled in labor. Freedmen and women who returned to plantations for their livelihoods post-Emancipation found themselves in a system of farm labor known as “sharecropping.” A contract was drawn up in partnership with a white landowner, and the labor provided by blacks in reality financially benefited the landowner, as any profits went back to him as he acted as both landlord and lender.

Along with the telegraph, the locomotive train allowed more Americans to stay connected while allowing for travel farther and quicker across the land than before. The American West witnessed other innovations with far-reaching consequences. The rise of

stockyards, twine self-binding harvesters, and track-type tractors provided efficiency and expediency on ranches and farms. In 1868, a patent was issued to Michael Kelly for barbed wire, metal fencing designed with short, twisted wire spikes to contain livestock and mark boundaries against trespassers. Mostly utilized to keep roaming livestock contained on a ranch, the impact on local Native populations was heavy, as it cut off water and hunting and diminished access to food sources. This also contributed to the end of the cowboy's long-haul cattle drives of previous generations as open land narrowed to private ranches enclosed by barbed-wire fencing, effectively cutting off access to well-established cattle drive routes long honored as shared open space. Barbed wire was not the only innovation to affect the wide-open expanses of the American West.

The Rise of Female Entrepreneurship

Women were not new to patenting mechanics or labor-saving devices for household or farm. Women's innovations as well as improvements on the designs of already-established devices ran the gamut of personal health and hygiene to ranch and household equipment and food production. Women's achievements and innovations often were accomplished anonymously, as social conventions of the day did not allow women to step out of their roles as homemakers, mothers, and helpmates to men. Nevertheless, records of the U.S. Patent Office reflect that many women defied gender conventions, repeatedly applying for patents under their own names. Many also patented their efforts under assumed male names masking their gender. Likewise, many women may have shared their work with husbands or another close male in order to achieve their goals.

One forum that allowed female participation was at World's Fairs and expositions in designated "women's sections," where acknowledgment of their inventions conformed to the accepted spheres. Patents by women appear in the 1800s for improving farm equipment such as a comb cotton-ginning device. Gelatin as a dessert was born in the kitchen of Rose Markward Knox (1857–1959), the inventor of flavored gelatin. Ice cream makers, eggbeaters, and dough mixers,

along with improvements on machines for sewing, ironing boards, and washing clothes and dishes, as well as for clothes-washing powder and liquid, appeared during the 1880s and 1890s. Many improved upon already-existing inventions. The automatic dishwasher idea came to Josephine Cochran in 1886. Margaret Colvin demonstrated her rotary washing machine at the Columbian Exposition in 1893. Colvin's patent for a washing machine was not the first; however, hers worked better than earlier versions. Sarah Goode's space-saving cabinet that unfolded to a bed became the first known patent by an African American woman in 1885.

Notable inventions of household improvements by men included the can opener designed in 1870 by William Lyman. Inventor Hiram Maxim not only invented the curling iron in 1866 but later the first successfully operated automatic machine gun in 1884. The shoe-lasting machine invented in 1883 by South American immigrant Jan E. Matzeliger revolutionized the footwear industry by speeding up the process of shoemaking.

Socially, the concept of leisure time and entertainment, still a new idea in mid-to-late-19th-century America, grew, thanks to the fact that industrialism brought in extra income and shorter workdays for the working classes compared to life on farms. Without duties associated with farm life, transplants to major cities found themselves with spare time. Amusement parks with roller coasters fueled recreation for a public looking for ways to spend its extra income and free time. What translated to leisure time for some, however, meant overwork, unsafe working conditions, exploitation, illness, and even loss of life. The rise in industrialism came with the demands for an increased labor force, and it included children. Children as young as seven, eight, and nine years of age were employed as operators in textile mills and coal mines, or they were sent to street corners to sell newspapers and produce. It would not be until the 1930s that the government enacted federal legislation banning underage children from the workforce. Reform often came in the mode of union membership. The Lady Stitcher's Union was one such union, organizing 3,000 women in 1886 who protested intolerable working conditions. Later, the International Garment Workers of America

would provide an even stronger platform for female immigrant sweatshop laborers in the wake of the Triangle Shirtwaist Factory Fire of 1911.

The Industrial Revolution Comes of Age

Technological advancement in 19th-century America crossed a broad spectrum of disciplines with the foremost breakthroughs in electrical energy, communication, and transportation. Financiers, industrialists, and entrepreneurs all shared an interest in unheard-of financial gain, all the while transforming the way Americans traveled, lived, and worked. Time and speed took on completely new dimensions as communication and transportation accelerated American life at rates unimaginable a generation earlier. The telegraph transmitted signals and sped communication faster than previously thought possible between cities. A transatlantic telegraph cable to Europe implemented by Cyrus W. Field in 1866 forever transformed communication between continents, which would prove important in the waging of world wars in later eras. Guglielmo Marconi's innovation sent radio signals across the ocean with similar impact. By 1876, the U.S. Patent Office registered a device that could transport human voices, allowing for communication across great distances. Inventors like Alexander Graham Bell (1847–1922) founded the Bell Telephone Company in 1877, and by 1899, it had become the American Telegraph and Telephone Company. Thomas Edison's (1847–1932) experiments and inventions of electricity and the electric lightbulb propelled the Edison Electric Light Company, chartered in 1878.

The information age spun forward rapidly as Americans utilized electric current not only in business but also socially. Americans of all walks of life took advantage of electric train cars, strolled through towns lit by electric lights, and forwent candles and gaslights in favor of electric lights at home in their parlors and at work in their offices.

Like many innovations of the era, America's first subway was funded by private industrialists. Early transportation had been horse-drawn railroads or streetcars. The first electrified streetcar system in Boston led to realizing the dream of a public subway system by inventor and engineer Frank Julian Sprague.

Sprague saw the first subway while in London in 1863—a coal-powered steam engine train that ran under the city. Created through the labor of Italian and Irish immigrants, America's first subway finished in 1897, built of concrete and steel.

The Industrialization of Leisure

The innovations of the 19th century not only harnessed energy far more efficiently, but they introduced time as a commodity and confronted class distinctions. Saving time meant more efficiency, and efficiency translated to dollars. The invention of elevators sped the transport of humans quickly to their destinations. Adding machines and typewriters cut the time it took to compose a letter more efficiently; then paper clips kept it all together. An expanding concept of freedom based upon individual fulfillment and personal self-determination evolved into participation in the expanding consumer marketplace and the freedom of leisure time.

Time as a commodity translated to a new concept of leisure transcending social class. Transitioning from a rural, farm, agrarian economy to the industrial, business-based economy found in cities, America found itself with leisure time. With dedicated hours in offices or service industries or factories, this labor force of women and men, after sending paychecks back home, found themselves with not only a little extra money but extra time to pursue life outside an office or factory. The impact was immeasurable, as it not only created industries and activities dedicated to fun, but it proved a great equalizer of the social classes. For the first time, factory workers dressed in their best Sunday clothes could spend the afternoon rubbing elbows with the elites as well as other factory workers enjoying amusements not heard of a decade earlier, redefining social mores and behavior. Luna Park and later Coney Island are case studies in culture rebelling against the stifling constraints of the Victorian Era. They challenged the ideals along with the social order of the time with regard to how people conducted themselves in public with each other.

New York's Central Park and Chicago's Columbian Exposition of 1893 are prime examples of the decorum expected in late-Victorian-era America.

There were expectations for how these amusements should be experienced. In keeping with Victorian ideals, Central Park and events like the Columbian Exposition were expected to maintain social order as well as create recreations for the public. The public was expected to conduct itself in a quiet, reserved manner while engaged in activities that were designed to promote learning and cultural refinement.

Frederick Law Olmsted, in collaboration with Calvert Vaux, designed New York's Central Park in 1858. It was intended as a retreat from the tumult of the city for all classes to enjoy. Olmsted's intentions, however, were to further the Victorian era's code of conduct to include a moral element intent on impressing upon the lower classes the necessity of conformity while endorsing upper-class lifestyles. Genteel behavior was the order of the day, and refinement was the rule. Traditional amusements of the Victorian era were carried out in venues such as bathing facilities band pavilions, dance halls, vaudeville theaters, and circus attractions. One might also find sporting events such as softball, football, and boxing. Any type of mechanical amusement with elaborate settings would be certain to draw a crowd. Still, most were considered spectator activities.

Early on, Coney Island was initially a dichotomy; one side of the park was for elites and the other half for gamblers and prostitutes. As time passed, the park opened for both, merging shop attendants and upper classes, where genteel behavior and refinement was not the rule. It was far from the skyscrapers of the city, offering new technology and architecture that had never been seen before. It also offered direct interaction with the amusements rather than passive watching from the sidelines, with no hint of educational value. The biggest impact that Coney Island had, however, was that it broke down restrictive social barriers imposed by Victorian standards and allowed for more freedom of exchange between the classes and between the sexes. This is what made it so different from other major amusements of 19th and early 20th century.

In 1861, Thomas Edison applied for a patent for a Kinematoscope, an early form of the motion picture camera. This device would display photos as if they were moving when someone simply wound the crank,

allowing the multiple photos to fall into place to give the illusion of movement. Edison's presentation at the World's Columbian Exposition of 1883 of his Kinetograph foreshadowed the birth of the "picture shows," or movies, using the celluloid film invented in 1889 by George Eastman of the Eastman Kodak Company.

Public Health and the Modern City

Across these decades, major strides would be made in medical sciences with government involvement, establishing overseeing bodies for public health and environment. The National Institutes of Health, formed in the 1870s, established a laboratory for the study of bacteria. By the end of the 19th century, the connection made between germs, their transmission, and hygiene and cleanliness did much to reduce mortality rates from deadly infections of typhoid fever and cholera. Penicillin and other new drugs reduced mortality rates among women and men. Women were living longer, and the birthrate continued to fall. Infant fatality also was on the decline in the United States. Despite progress in the field of public health, tuberculosis was still a health hazard. The spittoon or cuspidor, utilized by Americans to comply with laws limiting spitting in public, was still a fixture in public places into the 20th century, even though science had long known that any spitting could transmit tuberculosis.

Progress in public health and environmental issues came slowly. With the rise of factories and increased mining, not only did land and air quality suffer, but human health and significant loss of life came from heavy metal poisoning. Examples include the lung diseases of coal miners, as well as the wood and cigarette smoke that affected the broader population. The mines proved an environmental nightmare well into the 21st century. Diseases such as cholera and typhoid fever, whose route of transmission was unfiltered water, remained constant until the discovery of chlorine additives to public water sources in New Jersey dramatically reduced incidences of typhoid fever. Meanwhile, the harnessing of solar power to drive mechanical pursuits as an economical way to fuel devices like steam engines and the printing press went by the wayside as the use of coal and then petroleum

increased, with drastic environmental impact. The environmental cost to American soil due to industrialization would take a toll on riverways, while air quality in steel towns remains profoundly problematic to this day.

Late 19th and early 20th-century American technology and innovation centered on the production of goods and the early development of consumerism. Greater communication capabilities sparked the rise of newspaper muckrakers, who addressed profound social, political, and economic issues brought by the rise of industrialism and corporations. These had fueled tremendous wealth for a relative few, creating a widening gap between the wealthy and the working class and creating monopolies in industry.

By 1901, Theodore Roosevelt (1858–1919) would be the 26th president of the United States. He is considered the first modern president because of his support for progressivism, but principally because he embraced government responsibility for the common welfare of the nation both domestically and in foreign policy. Domestically, this meant using the office of the president to try to balance the power of big business (trust busting) and to reform politics to better address the tribulations caused by the Industrial Revolution of the earlier era. The Progressive Movement furthered reforms begun by the Populist Movement, tackling issues such as Prohibition, child labor laws, minimum wage, tenement house reform, antimonopoly legislation, food and drug regulation, and trust busting.

Brothers Wilbur and Orville Wright's successes with airplane flight catapulted Americans into the sky, leading the country into the next century, when Americans would travel into space.

Cynthia J. Parker

Further Reading

- Brinkley, Alan. 2000. *The Unfinished Nation. A Concise History of the American People*. Boston: McGraw-Hill Companies.
- Cadbury, Deborah. 2003. *Dreams of Iron and Steel. Seven Wonders of the Nineteenth Century, from the Building of the London Sewers to the Panama Canal*. New York: Fourth Estate, an Imprint of HarperCollins Publications.

Gordon, John Steele. 2004. *An Empire of Wealth. The Epic History of American Economic Power*. New York: HarperCollins.

Lamphier, Peg A., and Rosanne Welch, eds. 2017. *Women in American History: A Social, Political, and Cultural Encyclopedia and Document Collection*. 4 vols. Santa Barbara, CA: ABC-CLIO.

Porter, Glenn. 1973. *The Rise of Big Business, 1860–1920*. Chicago: Harlan Davidson.

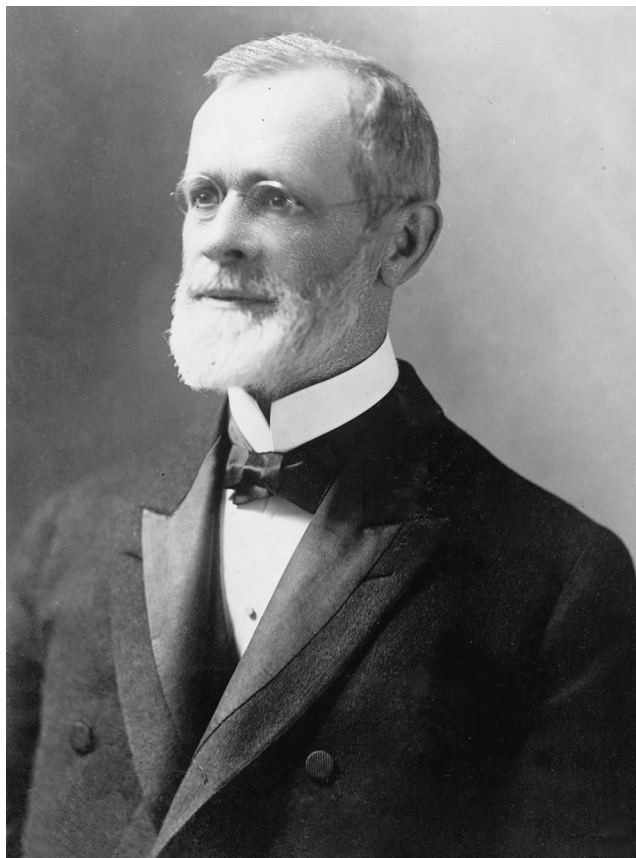
Stanley, Autumn. 1995. *Mothers and Daughters of Invention. Notes for a Revised History of Technology*. New Brunswick, NJ: Rutgers University Press.

Abbe, Cleveland (1838–1916)

Weather forecasting dates to the middle of the 19th century and can be largely attributed to the efforts of one man: Cleveland Abbe. It was his work and vision at the precursor of the National Weather Service that resulted in a widespread network capable of issuing reliable weather forecasts and severe weather warnings. Abbe also advocated for time zones in the United States.

Cleveland Abbe was born in 1838 in New York City. He was an astronomer and meteorologist who went by the nickname “Old Probability” due to his weather forecasting work. Abbe began this work during his time as the director of the Cincinnati Observatory in Cincinnati, Ohio, where he generated daily weather maps, weather forecasts, and even telegraphic weather reports. There, he also developed a code to transmit weather data, which minimized word count and allowed for faster and more efficient decoding of weather messages.

In 1872, he moved from the Cincinnati Observatory to the U.S. Weather Bureau and became the Bureau's chief meteorologist. Abbe's particular strength came in being able to generate weather forecasts and not simply summaries of already-past weather events. As the U.S. Weather Bureau was still very much in its infancy, for a short time, Abbe shouldered the workload while he trained others in weather forecasting based on scientific principles. He enlisted



The father of modern weather forecasting, Cleveland Abbe became chief meteorologist at the U.S. Weather Bureau in 1871. (Library of Congress)

young college graduates, who at the time were men only, to work at the Bureau.

In 1872, Abbe also founded the *Monthly Weather Review*, a scholarly journal devoted to weather forecasting. The *Review* was first a government publication under the auspices of the U.S. Army Signal Corps (of which the U.S. Weather Bureau was a department). The Weather Bureau was transferred to the U.S. Department of Agriculture in 1891, after which that department published the *Review*. From 1970 to 1973, the National Oceanic and Atmospheric Administration took over the Weather Bureau and the *Review*, but in 1974, the *Review*'s publication shifted to the American Meteorological Society, which still publishes the well-respected journal.

In 1891, when Congress moved the institution under the Department of Agriculture, most of Abbe's weather disciples followed. It was through his

mentorship and instruction that Abbe was able to set standards and establish the tone for the weather forecasting so familiar today. He insisted that every forecast that was issued had to cover weather, temperature, wind direction, and barometric pressure in precise and clear language. Cleveland Abbe recognized that for data from multiple stations across the country to be useful, they all had to be consistent in their time-keeping. This gave birth to his advocacy for time zones. He divided the United States into four standard time zones and published a paper titled "Report on Standard Time" in 1879, which played a large role in the government's decision to adopt a time zone system.

As the U.S. Weather Bureau became more established, Abbe realized the need for not just trained personnel but also technological advances. Along with his colleagues, he worked on calibrating various instruments, and in time, they designed and built instruments that pushed weather forecasting technology forward. Abbe had the foresight to realize that accurate weather predictions require a lot of data, often from outside the boundaries of the United States. Therefore, he bought and calibrated instruments adapted to international standards that facilitated international cooperation in weather data sharing.

Cleveland Abbe's contributions to his field were widely recognized. He published almost 300 scientific papers, and his authority was well known. He was one of the founders of the National Geographic Society. Starting from 1886, he was a professor at Columbian College, now George Washington University, and he was a lecturer at Johns Hopkins University from 1896 to 1914. He was awarded a PhD in 1891 from the City College of New York, his alma mater. Additionally, he received honorary degrees from the University of Michigan in 1888 and the University of Glasgow in 1896. Among his many accolades, Cleveland Abbe was an associate fellow of the American Academy of Arts and Sciences and also a recipient of the Symons Gold Medal from the Royal Meteorological Society as well as the Public Welfare Medal and the Marcellus Hartley Medal from the National Academy of Sciences. He died in 1916 in Maryland.

Stefka Tzanova

See also *Vol. 1, Sec. 1*: Astronomical Almanacs; Daylight Saving Time; Lightning Rod

Further Reading

Willis, Edmund P., and William H. Hooke. 2006. "Cleveland Abbe and American Meteorology, 1871–1901." *Bulletin of the American Meteorological Society* 87, no. 3: 315–26.

AC Generator and Transformer

The invention of alternating current (AC) generators and transformers was instrumental to the development of a workable electrical power distribution system. The first working AC generator was created in 1832 by Parisian inventor Hippolyte Pixii (1808–1835) and was steadily improved throughout the 19th century by other inventors, including William Stanley Jr. (1858–1916) and Nikola Tesla (1856–1943).

The first commercially successful AC transformer was produced by William Stanley Jr. (1858–1916) in 1883. Stanley did not invent the transformer; his design was based on earlier designs, such as the one created in 1882 by Lucien Gaulard (1850–1888) and John Dixon Gibbs (1834–1912).

Stanley was born in New York City and studied law at Yale University before leaving college to work in the nascent electric industry. During the early 1880s, he developed his understanding of electromagnetism and experimented with converting direct current (DC) to AC. In 1884, he went to work for George Westinghouse (1846–1914) and in 1885 was promoted to chief engineer.

That same year, Gaulard and Gibbs demonstrated a "secondary generator" in Italy. This transformer stepped down the dangerous high-voltage AC from transmission lines to lower voltages, making it safer and useful for powering lights and other equipment. Westinghouse bought the rights to their design and, at Stanley's request, ordered a 500-volt Siemens alternator (a type of generator) and a Gaulard and Gibbs transformer.

Stanley realized that the transformer was inefficient and set about making improvements. He first created an *E*-shaped core and wrapped the wiring in a way that provided better insulation. His design used parallel linkages, which helped to maintain the stability of the transformer's loads. Stanley also developed his own generator design to replace the Siemens alternator.

On March 20, 1886, Stanley demonstrated a fully working high-voltage AC power system in Great Barrington, Massachusetts. Wires were draped in elm trees along Main Street, and the generator and steam engine were housed in a disused factory south of town. The "Great Barrington Electrification" relied on Stanley's transformers, which were capable of converting a 500-volt generator output into 3,000 volts and stepping the voltage back down to 500 volts.

The demonstration was another salvo in the ongoing "war of the currents." Great Barrington already had an Edison direct current (DC) power system installed, but Stanley's AC power system proved it was able to handle more customers with less loss of power. Despite some problems with the generator, its success convinced Westinghouse to pursue AC power systems instead of DC systems.

In 1890, Stanley left Westinghouse and formed the Stanley Electric Manufacturing Company, which made and sold transformers. However, in 1903, the company was acquired by Westinghouse after a court battle over patent rights.

Karen S. Garvin

See also AC Induction Motor; Electricity, War of the Currents; Electrification, Urban; Tesla, Nikola

Further Reading

Jonnes, Jill. 2004. *Empires of Light: Edison, Tesla, Westinghouse, and the Race to Electrify the World*. New York: Random House.

Klein, Maury. 2008. *The Power Makers: Steam, Electricity, and the Men Who Invented Modern America*. New York: Bloomsbury Press.

McNichol, Tom. 2006. *AC/DC: The Savage Tale of the First Standards War*. San Francisco: Wiley.

Primary Document: American Institute of Electrical Engineers (AIEE) Member Biography for William Stanley (1934)

Although William Stanley died in 1916, the American Institute for Electrical Engineers (AIEE), a society to which Stanley belonged for many years, continued to recognize his contributions to electrical studies well after his death. The following is a biographical sketch honoring Stanley that appeared in the Institute's journal in 1934.

William Stanley was very prominent among electrical inventors and engineers who made possible long-distance light and power transmission; his inventions on the transformer and early work in the development of the a-c system contributed greatly to the advancement of the electrical art. During the earlier period of his career he was responsible for several incandescent lamp inventions, while in the employ of the United States Electric Company (1879–1881) and the Swan Electric company (1882–1883). From 1883 to 1884 he experimented on storage batteries and other apparatus in a private laboratory at Englewood, N.J. He then became associated with the Westinghouse organization, and installed and

equipped an incandescent lamp factory at Swissvale, Pa. In 1885, when because of illness he removed from Pittsburgh to Great Barrington, Mass., he set up a plant incorporating his ideas on long-distance light and power transmission, which distributed to the town 500 volts through transformers connected in multiple. The Westinghouse Company then took over the manufacturing details and installed the Stanley apparatus at Niagara Falls. In 1890 Mr. Stanley organized the Stanley Electric Manufacturing Company, which made the first of a long series of installations of the multiphase transmission system in 1894 at Housatonic, Mass., operating at 2,000 volts. In 1898 he organized the Stanley Instrument company. He also carried on an extensive consulting practice, until his death on May 14, 1916. He served the Institute on the Edison medal committee, from 1914 to 1916. He was born November 22, 1858, in Brooklyn, N.Y.

Source: American Institute of Electrical Engineers, Member biography for William Stanley, May 1934, Box HB-113. IEEE Archives, Piscataway, NJ.

AC Induction Motor

The alternating current (AC) induction motor was patented by Croatian American inventor Nikola Tesla (1856–1943) in 1888. Tesla's motor became a mainstay of the electrical industry due to its reliability and ease of maintenance, and it remains in widespread use today.

The principle of electromagnetic induction was discovered in the 1820s by English scientist Michael Faraday (1791–1867) and American scientist Joseph Henry (1797–1878) when they found that a magnetic field moving across a wire would produce an electric current. Throughout the early 19th century, scientists and engineers worldwide worked to develop alternating current into a workable electrical power system. Direct current motors were the norm, and existing alternating current motors were unreliable.

Tesla was working in France when he had an idea for building a motor that would use the electric current produced (induced) by a rotating magnetic field to provide torque for the motor. He realized that such a motor could be designed that so that it used a nonmoving stator and a moving armature, and would not need mechanical contacts.

In 1885, Italian physicist Galileo Ferraris (1847–1897) constructed an induction motor that used two-phase alternating current. But Ferraris did not patent his work; instead, he published his findings, which were quickly picked up by other scientists and engineers, including Tesla.

In 1887, Tesla demonstrated a working model of his induction motor. In October and November that year, he filed for patents for his two-phase induction motor AC system. On May 1, 1888, he was awarded patent number 381,968 for his "Electro Magnetic Motor." Tesla

presented his research on the motor at the May 16, 1888, meeting of the American Institute of Electrical Engineers. Shortly thereafter, he received an offer of employment from Westinghouse to work as a consultant.

The new motor design proved to be workable and quite versatile. Within two years, Tesla patented a series of modifications to his induction motor design, including a variable-speed option and a motor that would run from a polyphase power supply. His motors were also capable of starting even when heavy loads were applied to them, which made them well suited for industrial applications.

Tesla would later become embroiled in court battles to prove his patent claim for the AC induction motor. During the first court case, held in 1901 in Catskill, New York, the judge ruled in Tesla's favor, but later the Circuit Court of Appeals overturned the verdict. However, in 1905, the courts again ruled in favor of Tesla.

Karen S. Garvin

See also AC Generator and Transformer; Electricity, War of the Currents; Electrification, Urban; Tesla, Nikola; *Vol. 1, Sec. 3: Coil Magnet/Electromagnet*

Further Reading

- Carlson, W. Bernard. 2013. *Tesla: Inventor of the Electrical Age*. Princeton, NJ: Princeton University Press.
- Cooper, Christopher. 2015. *The Truth about Tesla: The Myth of the Lone Genius in the History of Innovation*. New York: Quarto.
- Jonnes, Jill. 2004. *Empires of Light: Edison, Tesla, Westinghouse, and the Race to Electrify the World*. New York: Random House.
- Klein, Maury. 2008. *The Power Makers: Steam, Electricity, and the Men Who Invented Modern America*. New York: Bloomsbury Press.

Primary Document: Nikola Tesla's Patent for an AC Induction Motor (1896)

The following is the text of Nikola Tesla's patent for an alternating current motor, an invention that many people believe deserves to be listed in the top 10 inventions of all time.

UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y., ASSIGNOR TO THE TESLA ELECTRIC COMPANY, OF SAME PLACE.

TESLA PATENT 555,190 ALTERNATING MOTOR.

SPECIFICATION forming part of Letters Patent No. 555,190, dated February 25, 1896.

Application filed May 15, 1888. Serial No. 273,993. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, a citizen of the United States, residing at New York, in the county and State of New York, have invented certain new

and useful Improvements in Electromagnetic Motors, of which the following is a specification, reference being had to the drawings accompanying and forming a part of the same.

In former patents granted to me—notably, Patents Nos. 381,968 and 382,280, of May 1, 1888—I have shown and described a system for the electrical transmission of power characterized by the following particulars: The motor contains independent energizing-circuits and the generator has corresponding induced or current-generating circuits which are connected by independent line-circuits with those of the motor, the said circuits being independent in the sense only that the distinctive relations of the currents produced, transmitted and utilized in each are preserved to produce their proper conjoint effect. The disposition of the generator coils or circuits is such that the currents developed therein and transmitted therefrom to the motor will have a certain difference of phase—for example, so that the maximum periods of the currents generated in one of such circuits coincide with the minimum periods of the currents produced in

the other circuit, and the corresponding energizing-circuits of the motor are so arranged that the two currents co-operate to effect a progressive shifting of the magnetic poles or the points of maximum magnetic effect in the motor, in consequence of which a rotation of its movable element is maintained.

My present invention pertains to this system of electrical transmission of power, its novel and distinguishing feature, however, being a special means for generating or producing in the two motor-circuits the alternating current necessary for the operation of the motor, for while in the instances referred to I produce both currents directly by a magneto-electric machine in the present instance I generate or produce in but one of the circuits of the motor directly an alternating current, and by means of such current induce in the other energizing-motor circuit the other alternating current necessary for its operation.

When the two currents are both produced in the magneto-electric machine, it will be observed that the two line or transmitting circuits will of necessity extend the entire distance from the generator to the motor; but by the plan herein provided one line-circuit only is required, as the circuit from the generator and the other are brought into inductive relation to each other in the motor itself.

The following is illustrative of a means by which I secure this result in accordance with my present invention: I employ as a motor, for example, a subdivided annular field-magnet within which is mounted a suitable armature, as a cylinder or disk, wound with two coils at right angles, each of which forms a closed circuit. On opposite sides of the annular field-magnet I wind two coils of insulated wire of a size adapted to carry the current from the generator. Over these coils, or close to them, in any of the well-understood ways, I wind secondary coils. I also wind on the annular field-magnet midway between the first-mentioned coils a pair of coils which I connect up in circuit with the secondary coils.

The last pair of coils I make of finer wire than the main or line and secondary coils, and with a greater number of convolutions, that they may have a greater relative magnetizing effect than either of the others.

By connecting up the main coils in circuit with a generator of alternating currents, the armature of the motor will be rotated. I have assumed that this action

is explained by the following theory: A current-impulse on the line passing through the main coils establishes the magnetic poles of the annular field-magnets at points midway between said coils; but this impulse produces in the secondary coils a current differing in phase from the first, which, circulating through the second pair of energizing-coils, tends to establish the pole at points ninety degrees removed from their first position, with the result of producing a movement or shifting of the poles in obedience to the combined magnetizing effect of the two sets of coils. This shifting, continued by each successive current-impulse, establishes what may be termed a "rotary effort," and operates to maintain the armature in rotation.

In the drawings annexed I have shown, in Figure 1, an alternating-current generator connected with a motor shown diagrammatically and constructed in accordance with my invention, and in Fig. 2 a diagram of a modified form of motor.

A designates any ordinary form of alternating-current generator, and B B the line-wires for connecting the same with the motor.

C is the annular field-magnet of the motor.

D D are two main coils wound on opposite sides of the ring or annular field and connected up with the line and having a tendency to magnify the ring C with opposite poles midway between the two coils.

E E are two other magnetizing-coils wound midway between the coils D D, but having a stronger magnetizing influence for a current of given strength than coils D D.

F F are the secondary coils, which are associated with the main coils D D. They are in circuits which include the coils E E, respectively, the connections being made in such order that currents induced in coils F and circulating in coils E will act in opposition to those in coils E in so far only as the location of the magnetic poles in the ring C is concerned.

The armature may be of any of the forms used by me in my alternating-current system, and is shown as wound with two closed coils G H at right angles to each other.

In order to prolong the magnetizing effect of the induced currents in producing a shifting of the poles, I have carried the principle of the construction

exhibited in Fig. 1 further, thereby obtaining a stronger and better rotary effect.

Referring to Fig 2, C is an annular field-magnet having three pairs or oppositely-located sets of polar projections K L M. Upon one pair of these projections, as K, the main energizing-coils D are wound. Over these are wound the secondary coils E. On the next polar projections L L are wound the second energizing-coils F, which are in circuit with coils E. Tertiary-induced coils E' are then wound over the coils F, and on the remaining polar projections M the third energizing-coils F' are wound and connected up in the circuit of the tertiary coils E'.

The cylindrical or disk armature core N in this motor has polar projections wound with coils O, forming closed circuits. My object in constructing the motor in this way is to effect more perfectly the shifting of the points of maximum magnetic effect. For, assuming the operation of the motor to be due to the action above set forth, the first effect of a current-impulse in this motor will be to magnetize the pole-pieces K K; but the current thereby induced in coils E magnetizes the pole-pieces L, and the current induced in turn in coils E' magnetizes the pole-pieces M. The pole-pieces are not magnetized, at least to their full extent, simultaneously by this means; but there is enough of a retardation or delay to produce a rotary effect or influence upon the armature. The application of this principle is not limited to the special forms of motor herein shown, as any of the double-circuit alternating-current motors invented by me and described in former Letters Patent to me may be adapted to the same purpose.

This invention, moreover, is not limited to the specific means herein shown for inducing in one energizing-circuit of the motor the currents necessary for co-operating with the primary current of the generator for producing the progressive shifting of the poles or points of maximum magnetic effect.

I believe that I am the first to produce any kind of motor adapted to be operated by alternating currents and characterized by any arrangement of independent circuits brought into inductive relation so as to produce a rotary effort or effect due to the conjoint action of alternating currents from a source of supply in one of the motor-circuits and alternating currents induced by the first-named currents in the other

circuit, and this without reference to the specific character or arrangement of the said two circuits in the motor.

What I therefore claim as my invention is—

1. In an electromagnetic motor, the combination of independent energizing-circuits, one adapted to be connected with a source of alternating current, the other arranged in inductive relation to the said first circuit whereby the motor will be operated by the resultant action of the two circuits, as set forth.
2. The combination in an electromagnetic motor, with an alternating coil or conductor and a closed-circuit conductor in inductive relation thereto, of an armature mounted so as to be within the field produced by the coil and closed conductor, as set forth.
3. The combination in an electromagnetic motor, with energizing-coils adapted to be connected with the generator of induced coils and independent energizing-coils in circuit therewith and arranged to produce a shifting movement of the points of maximum magnetic effect of the motor, as set forth.
4. The combination in an electromagnetic motor of a series of independent energizing-coils or sets of coils and induced coils wound on all the energizing-coils or sets of coils but the last of the series, the first energizing-coil or set of coils being included in circuit with a generator and each succeeding energizing-coil or set of coils being in circuit with the induced coils of the next preceding energizing-coils of the series.
5. In a system for electrical transmission of power the combination of an alternating-current generator, a motor with an energizing coil or coils connected with the generator, secondary coils in inductive relation to said energizing-coils, and energizing-coils in circuit therewith arranged in substantially the manner set forth to produce a movement or rotation of the points of maximum magnetic effect of the motor, as set forth.
6. In an electromagnetic motor the combination of independent energizing-circuits, one for connection with a source of alternating currents, the other in inductive relation to the first, whereby a

rotary movement or projection of the field-poles will be produced by the conjoint action of the two and an armature mounted within the influence of the field produced by the energizing-circuits and containing closed coils or circuits, as set forth.

NIKOLA TESLA.

Witnesses:

ROBT. F. GAYLORD,
FRANK E. HARTLEY.

Source: United States Patent Office, Letters Patent No. 555,190, dated February 25, 1896. Application filed May 15, 1888. Serial No. 273,993.

Adding Machine with Keys

William S. Burroughs (1855–1898) is recognized as inventing the adding machine. Burroughs's early career experience in banking, particularly with the number of calculations required for his clerical job, motivated him to develop his concept of a mechanical way to calculate—thus, the adding machine. Following his relocation from New York to Missouri, he focused his efforts on building the arithmetic machine. Burroughs finished the device in 1885.

The original design enabled users to add numbers, but it could only save the total sum, and this lack of practicality hindered effectiveness. With the support of three businesspeople, including financial backer Thomas B. Metcalfe, the group founded the American Arithmometer Company the next year.

After spending several years refining the prototype, the company released an improved model in 1892. This practical model was produced in high quantity due to increasing demand among banks and other business. Success of Burroughs's adding machine and business venture started a line of notable technology companies from the Arithmometer Company, including Burroughs, Sperry, and Unisys. During the first half of the 20th century, Burroughs became the largest producer of adding machines.

Eric G. Lovik

See also Cash Register

Further Reading

Turck, J. A. V. 1972. *Origin of Modern Calculating Machines*. Reprint ed. New York: Arno Press.

Amalgamated Clothing Workers of America (ACWA)

One of the first unions to accept female members, the Amalgamated Clothing Workers of America (ACWA) was a leading union representing workers in the men's clothing industry during the 20th century. Known for its commitment to "new unionism" that broke away from the traditional craft union model and for incorporating progressive and socialist ideology within modern business systems, the decision to accept female members proved a significant financial breakthrough for women who worked for wages.

The ACWA was founded in 1914 in response to dissatisfaction with the conservative policies of the United Garment Workers of America (UGW). The roots of the ACWA can be traced back to the 1910 Chicago Men's Garment Workers Strike, when unskilled female workers led by Bessie Abramowitz (1889–1970) walked off of their jobs. When their skilled male counterparts soon joined them, strike numbers grew to almost 40,000. Believing it a waste of time to organize unskilled, largely immigrant workers, the UGW was unresponsive. When the strike became violent five months later, the UGW secretly negotiated an agreement and the workers returned to their jobs with no concessions. Ultimately, the failed strike laid the groundwork for future unionization; it introduced strong, new leaders and increased frustration with the strikebreaking techniques of the UGW.

Sponsors of the UGW annual convention in October 1914 denied seats to most clothing worker delegations, deeming them anarchists out to break the union. Eventually, the various clothing representatives left

the annual meeting and reconvened to discuss their desire to break away from the UGW to form their own union. The Amalgamated Clothing Workers of America was established the following December under the leadership of Sidney Hillman (1887–1946), a key player in the Chicago strikes.

The ACWA emerged with an intense campaign to unionize workers, which was highly successful in Chicago, where a series of strikes beginning in 1915 led to union presence in shops. Hillman's policy of providing support for the strikers forced the companies to relent, and most of the large firms were organized. A large push in 1916 focused on female workers, who composed more than half of the men's clothing industry.

By 1920, the ACWA included 177,000 members (66,000 women) from across the United States and Canada and held contracts with 85 percent of men's clothing manufacturers in those countries. The influx of members and successful strikes allowed the ACWA to implement member benefits such as unemployment insurance, support for the families of striking workers, educational classes in English, day care centers, banking, and insurance for its members.

The organization created a women's department under the direction of Dorothy Jacobs Bellanca (1884–1946), who won a spot on the ACWA's national board in 1916 and became its first full-time female organizer in 1917. Bellanca, at the age of 14, had served as president for her newly organized local Baltimore Button-hole Makers Union and made her mark leading a successful strike. She would later serve as ACWA vice president from 1934 until her death in 1946. In strikes in many major cities, hundreds of women picketed and were arrested and jailed, often after initiating walk-outs. Despite their efforts, women lacked day-to-day support, and the women's department was a short-lived endeavor. In response, locals in many urban areas organized woman-centric programs and discussions.

As the economy declined in the late 1920s, the ACWA struggled to maintain its membership. The organization lent money to employers in an effort to preserve jobs and attempted to connect unemployed members with available jobs. In response to racketeers demanding protection money, Hillman worked to

expel organized crime and communism in the ACWA ranks. With member loss growing, the ACWA joined the American Federation of Labor (AFL). The connection with the AFL was short-lived, however, as Hillman joined with the United Mine Workers to form the Congress of Industrial Organizations (CIO) in 1935.

During World War II, the union benefited from securing government contracts for workers producing military uniforms and parachutes. Women in particular benefited from the creation of new wartime jobs. Encouraged by their success in the postwar climate, the CIO (now including the ACWA) started Operation Dixie, a campaign to unionize Southern workers. The ACWA was one of the only organizations to send female organizers into the field—but the operation failed.

In 1952, the ACWA signed a contract covering all workers in the men's clothing industry, the first of its kind in this field. Women continued to feel ignored by the leadership, however. In Bessie Abramowitz Hillman's speech (she and Sidney married in 1916) at a 1961 Industrial Union Conference, she accused male leaders of providing only token positions for their female counterparts and encouraged women to fight for recognition.

By 1973, the ACWA included 365,000 members, with larger numbers of Latino and Asian workers joining the ranks. It continued to petition businesses throughout the 1970s up until 1990 and won many victories in large firms across the United States, including a notable partnership with Levi Strauss in 1994.

The organization merged with the Textile Workers Union of America in the South, forming the Amalgamated Clothing and Textile Workers Union (ACTWU) in 1976, and it added the United Hatters, Cap and Millinery Workers International Union in 1983. The ACTWU then merged with the International Ladies' Garment Workers' Union, creating the Union of Needletrades, Industrial and Textile Employees in 1995, and, in 2004, that union merged with the Hotel Employees and Restaurant Employees Union to become UNITE HERE—which continues to represent workers throughout the United States and Canada. In 2009, many of the members split from the union and formed Workers United.

Stephanie M. Bayless

See also *Vol. 2, Sec. 3: International Ladies' Garment Workers' Union (ILGWU)*

Further Reading

Argersinger, JoAnn E. 1999. *Making the Amalgamated: Gender, Ethnicity, and Class in the Baltimore Clothing Industry, 1899–1939*. Baltimore: Johns Hopkins University Press.

Kessler-Harris, Alice. 2007. *Gendering Labor History*. Urbana: University of Illinois Press.

Pastorello, Karen. 2008. *A Power among Them: Bessie Abramowitz Hillman and the Making of the Amalgamated Clothing Workers of America*. Urbana: University of Illinois Press.

American Telephone and Telegraph Company (AT&T)

For most of the 20th century, American Telephone and Telegraph Company (AT&T) was the largest corporation in the world. In 1885, National Bell Telephone Company (NBTC) established AT&T to provide the first nationwide long-distance network. Deeming it a monopoly, the U.S. Department of Justice broke up AT&T in 1984. Throughout its history, AT&T built most of the U.S. telephone system, and the company's technological innovations served as a standard for the world's telephone industry.

Patents of various telecommunication innovations gave NBTC a tremendous advantage over its competitors. NBTC went through several transformations and name changes until AT&T became NBTC's parent company in 1899. Like NBTC, for much of its history, AT&T functioned without significant competition. In spite of the firm control that AT&T held over the telephone industry, the company's leadership was not content with stagnation. One way that AT&T executives sought to remain ahead of competitors was through continual technological innovation. For example, the company rolled out the first coin-operated public telephone (1889) and four-party service (1891). The company also patented the first automatic dialing system in 1891.

The installation of long-distance lines was expensive, and AT&T (incorporated in 1885) often sold

bonds to raise the needed funds. In 1892, the company opened a long-distance telephone line from New York to Chicago. The next year, it opened lines from Boston to Chicago and from New York to Cincinnati. Nationwide, the number of telephones using AT&T service jumped from 240,000 in 1892 to 800,000 in 1899. Unfortunately, by the late 1800s, many of its patents had expired. To keep costs down and maximize profits, AT&T formed alliances with many companies from around the world that produced low-cost telephone equipment. By 1900, AT&T had assets totaling \$120 million.

By the early 1900s, a multitude of competitors collectively gained 51 percent of the telephone market. However, AT&T continued to hold a monopoly over long-distance service. During the late 1800s, AT&T had developed a reputation for poor customer service. However, competition convinced company executives to adopt a new business philosophy that balanced profits with customer satisfaction. Additionally, continued innovation was seen as the best way to regain the majority of the market. During these years, AT&T began using the loading coil, a small electronic device that allowed for the use of smaller-diameter wires. The new technology made it possible, for the first time, to use long-distance underground cables.

By 1906, long-distance underground cables connected New York and Philadelphia. Although underground cables had lower transmission losses than overhead cables, long-distance signals remained weak and difficult to hear. To address this problem, in 1912, AT&T implemented the vacuum-tube repeater. During World War I (1914–1918), AT&T supplied domestic and foreign military telephone service under the leadership of the U.S. government. Military leaders placed AT&T under a branch of the U.S. Postal Service, and there was talk about making the move permanent. However, after the war, support faded for government ownership of AT&T. By 1918, AT&T had 10 million phones in service.

In 1921, AT&T installed the first undersea cable connecting Key West, Florida and Havana, Cuba. To continue to promote innovation, AT&T created Bell Labs. Although Bell Labs's ventures were mostly focused on improving telephone technology, research and development included a wide range of

technological interests. For example, in 1929, engineers demonstrated a prototype of the color television. Due in great part to friendlier customer service, telephone innovations, and infrastructure expansion, during the 1920s and 1930s, AT&T secured a much greater hold on the telephone market. Although many smaller independent companies existed, most of them had no choice but to connect their phones to AT&T lines.

By 1939, AT&T controlled 83 percent of all U.S. telephones and 98 percent of long-distance wires. During World War II (1939–1945), there was a great demand for long-distance communication. More than a million new telephones were installed in 1941 alone. In 1948, Bell Labs created the transistor, which replaced the vacuum tube in telephone networks. Compared to vacuum tubes, transistors were less expensive and much smaller. In 1956, Bell Labs was awarded the Nobel Prize for the introduction of the transistor, which had applications far beyond telephone use. Bell Labs developed cellular phone wireless technology (1947), the computer modem (1957), and communication satellites (1962) that orbited the earth and facilitated worldwide telephone communications. In 1965, the development of electronic switching systems permitted a vast increase in telephone traffic and also set the stage for later Internet traffic.

By the 1980s, AT&T employed more than 1 million people. The federal government ruled that AT&T was a monopoly and ordered that it be dismantled. In 1984, when it was broken up, the company's assets totaled about \$155 billion, which was more than the assets of General Motors, Mobil, and Exxon combined. Even though AT&T's share of the long-distance market began to steadily decline after the breakup, the company still held a great part of the market. Its share of long-distance telephone service based on minutes of use were 85 percent in 1984, 80 percent in 1985, 75 percent in 1986, and 70 percent in 1988.

As early as the 1980s, AT&T began focusing on computer and Internet technologies. In the 2000s, AT&T expanded its international and domestic wireless streaming technology services. After purchasing the Mexican carrier Iusacell and the Mexican wireless business of NII Holdings, the company combined the two to form AT&T Mexico in 2014. Domestic

expansion included the purchase of Time Warner in 2016 and DirecTV in 2017. By 2018, AT&T was planning to launch an innovative cable TV–like service through its broadband network.

Rolando Avila

See also Bell, Alexander Graham; *Vol. 1, Sec. 3: Telegraph*; *Vol. 2, Sec. 3: Telephone*; *Vol. 3, Sec. 1: Telephone Switching, Computerized*

Further Reading

Evans, David S., ed. 1983. *Breaking Up Bell: Essays on Industrial Organization and Regulation*. New York: Elsevier Science.

Sims, Calvin. 1989. "AT&T's New Call to Arms," *New York Times*, January 22, F1, F11.

Wasserman, Neil H. 1985. *From Invention to Innovation: Long Distance Telephone Transmission at the Turn of the Century*. Baltimore: Johns Hopkins University Press.

Asphalt

Though the word "asphalt" properly means any sticky residue of petroleum, it is most commonly used to describe a petroleum distillation combined with mineral aggregate (gravel) that is used to surface roads. Edward J. de Smedt invented modern road asphalt in 1870. Asphalt is ubiquitous in contemporary America, covering 94 percent of all road surfaces.

Before the invention of asphalt, road builders and civil engineers struggled to develop an easy-to-use, durable road surface. Indeed, one of the reasons for the early 19th-century popularity of railroads and canals lies in the poor condition of American roads at the time. Poor roads translated to slow transportation of goods and people. The most effective roads were made of layers of broken rocks, the depth of which was calculated against the road's weather and traffic. Rock proved difficult to find in some areas and heavy to move in all areas, and the resultant roads were far from smooth.

In the late 1860s, Edward de Smedt immigrated to the United States from Belgium. He patented asphalt, more popularly called "French asphalt cover," in 1870

while employed by Columbia University. He first applied it to a Newark, New Jersey, road. When that experiment proved successful, he laid his first road cover in New York's Battery Park in 1872.

While asphalt exists naturally, most notably in the La Brea Tar Pits in Los Angeles, California, the bulk of asphalt is manufactured from crude petroleum oil. Fuel and motor oil is first extracted from the naturally occurring oil, and the substance remaining, sometimes called tar, becomes asphalt. Asphalt is an affordable, durable road surface, though it is not environmentally friendly or sustainable. In 21st-century America, asphalt covers most parking lots and roads. It is also used on airport runways and on the driveways of private houses. Asphalt, or roof tar, is also applied to paper used in building roofs.

Peg A. Lamphier

See also *Vol. 2, Sec. 2: Automobile Technologies (Pre–World War II); Petroleum Industry (Pre–World War II)*

Further Reading

National Center for Asphalt Technology. 2009. *Hot Mix Asphalt Materials, Mixture Design, and Construction*. 3rd ed. Auburn, AL: Auburn University.

Aspirin

Aspirin (acetylsalicylic acid or ASA) is a white, crystalline substance derived from salicylic acid. While modern aspirin is synthetically produced, salicylic acid occurs naturally in many plants, including the willow tree, from which it gets its chemical name (the Latin name for the willow plant is *salix*).

The use of willow bark and leaves as a treatment for illnesses is believed to go back about 3,000 years. It is mentioned in the Ebers Papyrus, an Egyptian medical scroll of herbal knowledge dating to around 1550 BC. Hippocrates, the Greek physician who lived from about 460 to 377 BC, also wrote that willow leaves and bark relieved pain and fevers.

However, it wasn't until hundreds of years later that more attention was brought to willow bark's effects. In 1757, an English clergyman, Edward Stone,

essentially rediscovered its properties. He happened to taste some of the bark (no one is quite sure why) and noticed that its bitter flavor was quite like that of the bark of the cinchona tree. Cinchona contains quinine, which is used as a treatment for malaria.

Stone was excited about the possibility of finding a local plant that could treat malaria, because the tropical cinchona tree only grew in South America, making the bark expensive and hard to get. He dried some willow branches and ground them into a powder, giving it to family and friends who were suffering from fever and chills. In 1763, he wrote a report on how it had benefited 50 people to whom he'd given it. Their fever, chills, aches, and pains had disappeared, at least temporarily.

In the 1800s, as scientific advances began to speed up the understanding of the actions of naturally occurring drugs, researchers across Europe started to try to isolate the active ingredient responsible for their healing effects. German pharmacy professor Joseph Buchner was the first to isolate salicylic acid in 1828, in the form of bitter yellow crystals that he called "salicin."

In 1829, French chemist Henri Leroux improved on Buchner's process, and in 1838, Italian chemist Raffaele Piria refined it even further, calling his more potent isolate "salicylic acid." Reports of the beneficial properties of salicylic acid spread quickly, and demand grew. Chemistry professor Hermann Kolbe worked out its chemical structure and succeeded in making it synthetically in 1859. This allowed salicylic acid to be produced on an industrial scale, and by 1874, a factory in Dresden was able to offer it for sale at a tenth of the price of the natural substance extracted from willow bark.

There was a problem with salicylic acid, however. It was extremely bitter tasting and very corrosive to the mouth, throat, and stomach—so much so that some patients refused to take it, preferring the less potent salicin crystals. It would take the work of a young chemist 23 years later to solve the problem.

That chemist, Felix Hoffmann, was born in 1868 in Ludwigsburg, Germany. After graduating from Munich University, he was hired by Friedrich Bayer & Company in 1894 as a pharmaceutical chemist. Bayer, founded in 1863 as a dye company, was expanding

beyond its initial ambitions and was assembling a team to discover and mass-produce drugs.

There are conflicting stories about how Hoffmann came to work on the project. Some sources, including Bayer & Company itself at one time, say that Hoffmann took up the challenge on his own initiative because his father suffered from painful rheumatism and found salicylic acid too hard on his stomach.

Newer research, however, has shown that it is much more likely that he was assigned the project by his supervisor, Arthur Eichengrün, who thought a compound with fewer side effects could be commercially successful. What is agreed upon is that on August 10, 1897, Felix Hoffmann wrote in his laboratory journal that he had created a substance—acetylsalicylic acid, or ASA—that neutralized the chemical element of salicylic acid that was responsible for its most corrosive effects.

Curiously, the new drug was initially rejected by the head of Bayer's testing department due to the erroneous belief that it was bad for the heart; large doses of salicylic acid could cause rheumatic fever patients' hearts to race, and it was his feeling that this drug would be no different.

Arthur Eichengrün, upset by the rejection, sent some samples of ASA to Felix Goldmann, a Bayer representative in Berlin. Goldmann gave them to doctors there and received glowing reports on its effectiveness and palatability. It was sent into testing again and approved for production.

The new drug then needed a name. The *a-* in aspirin comes from the process that Hoffmann used to create it: acetylation. The middle letters—*spir*—come from *Spiraea*, a biological genus of shrubs that contain natural sources of salicylic acid. The *-in* was added to make the word easier to say.

Production of aspirin started in July 1899. Initially packaged as a powder in glass jars, parcels of it were sent to hospitals and pharmacists across Europe as its manufacturer touted the drug's reduced gastric irritation and analgesic effects. Within 15 years, aspirin became one of the most widely used drugs in the world. Due to a quirk in German patent laws, however, Hoffmann made no money from his discovery.

Recent research has revealed that aspirin treats more than fever and pain. It has been found to reduce

the incidence of blood clots and is often prescribed to prevent heart attacks and strokes. Aspirin may also prevent certain types of cancer. Today, four out of five people with heart disease use aspirin regularly, according to data from a 2006 Centers for Disease Control and Prevention study.

Nancy Beach

See also Vol. 3, Sec. 1: Antibiotic; Vaccines

Further Reading

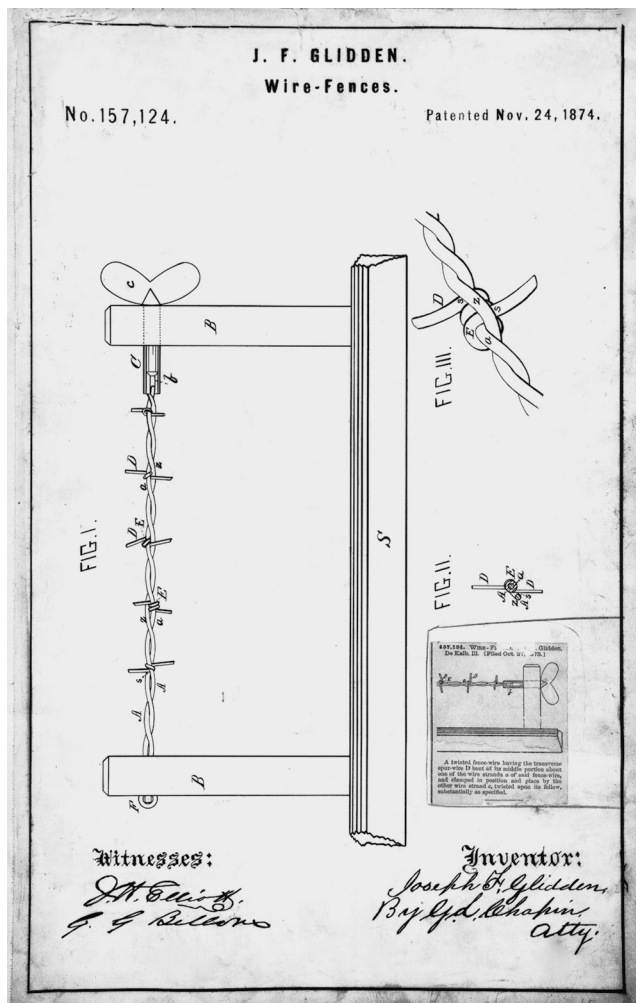
- Jack, D. B. 1997. "One Hundred Years of Aspirin." *The Lancet* 350: 437–39.
- Jeffreys, D. 2004. *Aspirin: The Remarkable Story of a Wonder Drug*. <https://books.google.com/books?id=v9AZ76VD7ZYC&lpg=PR7&pg=PA27#v=onepage&q&f=false>, accessed August 28, 2018.
- Landau, E. 2010. "From a Tree, a 'Miracle' Called Aspirin." <http://www.cnn.com/2010/HEALTH/12/22/aspirin.history/>, accessed August 28, 2018.
- Sneader, W. 2000. "The Discovery of Aspirin: A Reappraisal." *British Medical Journal* 321: 1591–94.

Barbed Wire

Barbed wire was invented in the 1800s to prevent cattle from wandering the vast American plains. During World War I, however, it contributed to the deadlock on the Western Front, and tangles of wire came to symbolize the industrialized nature of the war and the inhumanity of its violence.

Humans in antiquity made wire to make jewelry and later used it for practical purposes such as the manufacture of pins and wool cards (brushlike devices for combing wool fleece). Demand for wire increased in the industrial era, especially after the invention of the telegraph. During the American Civil War, both sides used telegraph wire for military purposes. In addition to using it in communications, soldiers strung telegraph wire between trees, stumps, and rocks to trip up attackers and break up formations. The tactic was moderately successful but failed to have a major impact on military planning and strategy.

In 1874, a 60-year-old Illinois farmer, Joseph F. Glidden (1813–1906), patented the first successful



Joseph Glidden applied for a patent on barbed wire fences in 1874, even though Lucien Smith had earned one in 1867. The Barbed Wire Patent court case that followed dealt with questions of first to file and scope of novelty. Glidden won the case. (National Archives)

barbed wire. He recognized that the lack of trees on the American plains made it impossible to control livestock with traditional wooden fences. Glidden used a coffee grinder to make barbs that he placed at regular intervals on a wire. Another wire was then twisted with the original strand to keep the barbs from slipping. The result was a lightweight fencing material that could be used anywhere. The demand for barbed wire was coupled with the simultaneous development of cheaply produced steel. In 1901, the United States produced over 135,000 tons of barbed wire, and the open range was no more.

Military leaders soon recognized barbed wire's value in defensive positions. In 1888, British military manuals recommended its use. During the Spanish-American War, American troops used strands of barbed wire to defend their camps from surprise Spanish attacks. One of the most controversial uses of the fencing materials was during the South African (Boer) War. During that conflict, British forces used lines of blockhouses and barbed-wire fences to cut off Boer forces from their civilian supporters. Both black and white South Africans were herded into concentration camps and fenced in. In the Russo-Japanese War of 1904–1905, Russian forces defending Port Arthur used multiple lines of barbed-wire obstacles to blunt Japanese assaults.

The Russo-Japanese War was a rehearsal for World War I in many ways. By November 1914, warfare on the Western Front had settled into a deadlock of trench lines from Switzerland to the English Channel. Specially produced military barbed wire, with larger barbs, was strung in thick belts by both sides to protect the trenches. When coupled with machine guns, the wire was an almost impenetrable obstacle. Special pickets to hold the wire consisted of two flat pieces of steel, formed into an L shape. Slots on the side held the wire in place. The pickets were either driven into the ground or had a screw attachment for silent emplacement. Attempts to cut the wire with artillery shells were usually unsuccessful. The flexible wire either sprang back to its original position or blew into the air, landing in a more impenetrable mess than before. Infantry that attacked enemy trenches were often stopped by wire with no gaps and cut down by machine guns.

Attacking infantry units had to force their way through the wire. Wire cutters were used to create gaps, but it was slow work and usually attracted enemy fire. Grappling hooks were sometimes used to drag the wire out of place, with limited success. Other methods included covering the wire with boards, blankets, or human bodies to allow soldiers to run across. Explosives, such as Bangalore torpedoes (explosive devices placed at the end of a long, expandable tube), were sometimes used to blow holes in the wire. The need to overcome the combination of barbed wire and machine guns led directly to the invention of the tank by the

Allies. Tanks were able to crush the wire or drag it out of the way of following infantrymen.

Barbed-wire obstacles became one of the most enduring images of trench warfare. Small parties of men slipped out of the trenches at night to put up or repair their own wire or to cut the enemy's. In the aftermath of attacks, dead or seriously wounded soldiers were often left on the wire. Their bodies, slowly decomposing, became one of the many horrors of the war.

Timothy J. Watts

See also Vol. 1, Sec. 2: Steam Tractor; Three-Piece Iron Plow; Vol. 1, Sec. 3: Mechanical Reaper

Further Reading

- Dupuy, Trevor N. 1980. *The Evolution of Weapons and Warfare*. Indianapolis: Bobbs-Merrill.
- Krell, Alan. 2002. *The Devil's Rope: A Cultural History of Barbed Wire*. London: Reaktion.
- McCallum, Henry D., and Frances Tarlton McCallum. 1965. *The Wire That Fenced the West*. Norman: University of Oklahoma Press.
- Netz, Reviel. 2004. *Barbed Wire: An Ecology of Modernity*. Middletown, CT: Wesleyan University Press.
- Rezac, Olivier. 2002. *Barbed Wire: A Political History*. New York: New Press.

Primary Document: Excerpts from an Article on Joseph F. Glidden and the Barb-Wire Industry (1884)

In its January 5, 1884, issue, The Prairie Farmer: A Weekly Journal for the Farm, Orchard and Fireside published an article summarizing the life of Joseph F. Glidden, the inventor of barbed wire, and describing the current state of the barbed-wire industry. The article clearly indicates the great impact that the invention of barbed wire had on farming and ranching in the United States. Reproduced here are excerpts from that article.

Joseph Farwell Glidden, "the Father of the Barb-Wire Business" of this country, is now a hale and hearty man of seventy-one. He was born at Charleston, N.H. When about one year old the family came West, to Clarendon, Orleans county, New York, and engaged in farming. The young lad, besides mastering the usual branches taught in the common schools, gave some time to the higher mathematics and Latin, intending to take a college course, an idea that he finally abandoned. He taught in the district schools for a few terms. In 1842 he came to Illinois and purchased a quarter section of land a mile west of what is now the site of the pleasant and prosperous town of DeKalb. With the exception of three years his life since then has been passed upon this farm and at DeKalb. He has from time to time added to his homestead, his farm now embracing 800 acres. His land is

under excellent cultivation, a considerable portion of it having been thoroughly tiled, and his farm buildings are first-class. Mr. Glidden has been twice married. Two children were born of the first union, both dying in infancy. By his second marriage he has one daughter, now the wife of a Chicago merchant.

Mr. Glidden has held several local offices of trust and honor and enjoys in a marked degree the esteem and confidence of the citizens of his neighborhood and county. The rapid accumulation of property of late years, through his barb-wire patents and business, gave him the means to gratify his feelings of public spirit, and in consequence the town of DeKalb has benefited greatly at his hands. Its leading hotel and many other buildings are the work of his enterprise. Mr. Glidden has never lost the simple manners of the farm. He is unostentatious, quiet, genial, and at his hotel makes everybody feel as much at home as though enjoying the hospitalities of his private house. His kindly, firm, and intelligent face is well shown in the accompanying portrait, though, as is usually the case, the hand of the artist has touched his features more lightly than has the hand of time.

Few names are now more widely known among the land holders of the country than that of Joseph F. Glidden, the unpretending gentleman whose life we have briefly sketched. It was his fortune to seize upon

an idea, and push it to development, which has not only given him fame and fortune, but which has enriched many others and saved many millions of dollars to the farmers of America. He has not only founded a mammoth industry, but he has revolutionized an economic system of the world. By his ingenuity and perseverance the fencing system of a pastoral continent has been reduced to a minimum of expense and simplicity. Not that he individually has accomplished all this, but as the patentee of the first really successful barb-wire fence, he laid the solid foundation for it all.

The first application for a patent for the Glidden barb was filed October 27, 1873. For some weeks previous to this date Mr. Glidden had had in his mind the idea of a barb of wire twisted about the main wire of the fence, leaving two projecting points on opposite sides. He made some of these by hand with the aid of pinchers and hammer. He strung two wires between two trees and twisted them together with a stick placed between them. A pair of cutting nippers was the next addition to his "kit" of tools. His next means for twisting the two wires together was the grindstone—attaching one end of the wire to shaft and crank, the others being fastened to the wall of the barn. And here, as in most things great and small in this world, woman furnished the motor power. The strong arm of the good helpmeet, Mrs. Glidden, turned the grindstone that twisted the first wire that made the first Glidden barb fence that kept stock at bay in Illinois or the world. Then followed a device for twisting and barbing, and the application of horse power. Business expanded, and steam took the place of the horse, and inventive genius modified and improved the entire machinery, it being estimated that at least the sum of \$1,000,000 has been expended in bringing the machinery for barb-wire making to its present state of perfection.

At about the same time that Mr. Glidden was wrestling with his ideas and devices, Mr. I.L. Ellwood was experimenting to accomplish a like result with a thin band of metal, the barbs cut and curved outward from the strip. In the meantime Mr. Glidden had put up a few rods of his hand-made barb-wire along the roadside at his farm. And here again the good genius of woman enters upon the scene. One Sunday Mr. Ellwood and his wife were driving along this road

and attracted by the wire fence stopped to examine it. Mrs. Ellwood, much to the chagrin of her husband, remarked: "This seems to me a better device than your own, don't it to you?" It did not then, for the remark disappointed and angered him. But it set him to thinking and before the next morning he was of the same opinion. The two men meeting the next day it did not take long to compromise and unite. Mr. Ellwood dropped his own plans and accepted a half interest in the Glidden patents, and assumed the management of the business end of the concern, in which position he developed ability and tact possessed by few business men in this country.

The barb-wire fence met an unexpected and general demand. We know of few things like it in the history of manufactures. From [Pg 2] this small beginning, scarce ten years ago more than fifty large establishments are now turning out this wire to meet an ever insatiate demand. The establishment of I.L. Ellwood (making the Glidden wire) at DeKalb is the most complete and extensive of them all. The building is 800 feet in length, and is supplied with about 200 machines for twisting and barbing the wire. It gives, when running full force, employment to about 400 men, and turns out a car-load of wire each hour for ten hours per day, on an average, though this amount is considerably increased at certain times of the year. These figures, though not given us by Mr. Ellwood, we are satisfied do not overstate the production of this one factory. The progress of the barb-wire industry of the whole country is shown by the following record of the past nine seasons. In

1874 there were 10,000 lb made and sold.
 1875 there were 600,000 lb made and sold.
 1876 there were 2,840,000 lb made and sold.
 1877 there were 12,863,000 lb made and sold.
 1878 there were 26,655,000 lb made and sold.
 1879 there were 50,337,000 lb made and sold.
 1880 there were 80,500,000 lb made and sold.
 1881 there were 120,000,000 lb made and sold.
 1882 there were about 180,000,000 lb.

The record for 1883 is not yet made up, but will probably show a corresponding increase.

In 1876 Mr. Glidden disposed of his half interest in the concern of Glidden & Ellwood to the

Washburn & Moen (wire) Manufacturing Company, of Massachusetts, receiving therefor \$60,000 in cash and a royalty on the future goods manufactured, Mr. Ellwood retaining his interest. The new concern began the purchase of prior unused and conflicting patents involving itself in extensive litigation, but, sustained by the courts, soon gained control of almost the entire barb-wire business of the country.

Nearly all wire-making companies are now running under license from the parent concern.

Source: “Joseph F. Glidden: The Barb-Wire Industry—Some Facts in Its Early History Not Generally Known—Its Growth.” *The Prairie Farmer: A Weekly Journal for the Farm, Orchard and Fireside*, Vol. 56: No. 1, January 5, 1884, 1–2.

Batteries

Batteries are relatively small devices for the conversion of chemical energy into electricity. They allow for the portability of devices that require a permanent electrical connection.

A battery consists of one or more cells (electrodes) called “cathode” and “anode”; these are the positive and negative terminals respectively. The terminal’s position depends on the direction of electricity flow. There is a liquid called an “electrolyte” between the electrodes that serves as the connection that allows the transfer of ions between them. The type of electrodes and electrolyte used depends on the rating of the battery—how much voltage and amperage it is designed to produce. The time that a battery runs depends on the size of the electrodes, since there is a finite number of ions that can be transferred between them.

The first battery was invented in 1800 by Italian inventor Alessandro Volta. There have been many improvements in them since. The most important is in the size, which has allowed technology to be more portable than ever. They are used in a wide range of devices such as small wristwatches, cell phones, portable computers, and hearing aid devices as well as airplanes, cars, and boats. There are two main types of batteries in current use: primary and secondary.

Primary batteries are the most common. They are used for low-current devices and are meant for one use only, because the chemical reactions that produce electricity in them are hard to reverse. The only possible way to reuse these batteries is to replace the

electrodes, but such a task is hard to do for the average person. These batteries are disposed of after a single use. Secondary batteries are commonly known as “rechargeable batteries.” They require charging before they are first used, but once they have been drained of all their current, they can be recharged by applying current to them, reversing the discharging process.

Batteries are on the verge of changing the automotive industry. Tesla Motors has taken the lead in that respect, though many other automotive companies have introduced electric cars utilizing batteries. Electric cars, from the Honda Prius to the Nissan Leaf, use battery technology to replace petroleum-fueled combustion engines.

In the 21st century, batteries have become increasingly environmentally unsustainable. Toxins in batteries poison the environment. This is a particular problem for electric car batteries. Rechargeable batteries ameliorate this problem, but the problem remains.

Peg A. Lamphier

See also AC Generator and Transformer; Metal Electrode Weld; *Vol. 1, Sec. 3: Electric Street Railway*

Further Reading

Fletcher, Seth. 2012. *Bottled Lightning: Superbatteries, Electric Cars, and the New Lithium Economy*. Hill and Wang.

Schlesinger, Henry. 2011. *The Battery: How Portable Power Sparked a Technological Revolution*. HarperCollins.

Bee Smoker

Moses Quinby invented the modern bee smoker in 1875. He was also the first American to keep bees for commercial purposes. Born in 1810, Quinby became known as the “Father of Practical Bee Keeping” for his astute observations on bee behavior and needs. Quinby believed that his knowledge should be freely shared. To that end, he wrote *Mysteries of Bee-Keeping Explained* in 1853. The same year, Lorenzo Langstroth published his book *Langstroth on the Hive and Honeybee*. The two books became the foundation of commercial beekeeping in America. In addition to inventing the first bee smoker, Quinby also developed the first centrifugal extractor for removing honey from wax combs.

Beekeepers have long known of the calming effect of smoke on bees, though until Quinby invented the smoker, the ability of a beekeeper to effectively harness this soporific effect was limited. Bee smokers are generally small enough to be handheld. They consist of a chamber and spout, not unlike those of a coffee pot or teapot, attached to a bellows. Beekeepers start a fire inside the smoker’s body, fueled by twigs, leaves, cotton, and more, and close the lid so that the fire smolders, producing smoke. The bellows are then employed to pump smoke from the spout onto the bees. The smoke does not harm the bees but makes them lethargic and of less danger to the beekeeper, who must not only have access to the bees’ honey but

must also on occasion check the hive for sickness or pests, feed the bees, and observe the queen’s condition.

The mechanism whereby smoke makes bees “sleepy” was not understood until the 20th century. Guard bees emit pheromones that alert other bees to danger and send them into attack mode; smoke masks these chemicals. Smoke also sends the colony into a feeding frenzy, as bees consume honey so that the hive can be rebuilt after a fire. Bees with full stomachs cannot effectively sting, because their abdomens are too distended to allow them to flex for that.

Today, beekeeping supply houses sell easy-to-use materials for bee smokers. Pulp paper blocks and compressed cotton wads are among the most popular. Bee smokers come in a variety of sizes and shapes, but all share the same basic anatomy as Quinby’s original design.

Contemporary American beekeeping is a multi-million-dollar industry (\$304 million in 2017). Beekeepers collect and market not only honey but also royal jelly, queen bees, pollen, and venom.

Peg A. Lamphier

See also Can Opener

Further Reading

Jackson, Paul. 2014. *Smoking Allowed—A Pictorial Past of Honey Bee Smokers in the United States*. London: Northern Bee Books.

Primary Document: Excerpt on the Use of a Bee Smoker from Moses Quinby’s *Mysteries of Bee-Keeping Explained* (1853)

*Moses Quinby was one of the first commercial beekeepers in the United States. In 1853, he wrote *Mysteries of Bee-Keeping Explained*. The following excerpt from it deals with the soporific effect of smoke on angry or swarming bees and suggests a model for a handheld bee smoker to pacify them. Quinby wrote his book in easy-to-read and exceptionally engaging language.*

THEIR MANNER OF ATTACK.

I must disagree with any one who says we always have warning before being stung. I have been stung a few times myself. Two-thirds of them were received without the least notice—the first intimation was the “blow.” At other times, when fully determined on vengeance, I have had them strike my hat and

remain a moment endeavoring to effect their object. In this case, I have warning to hold down my face to protect it from the next attempt, which is quite sure to follow. As they fly horizontally, the face held in that position is not so liable to be attacked. When they are not so thoroughly charged with anger, they often approach in merely a threatening attitude, buzzing around very provokingly for several minutes in close proximity to our ears and face, apparently to ascertain our intentions. If nothing hostile or displeasing is perceived, they will generally leave; but should a quick motion or offensive breath offend them, the dreaded result is almost sure to follow. Too many people are apt to take these threatening manifestations as positive intentions to sting. When these things can be quietly endured, and at the same time leave their vicinity, it generally ends peaceably. They never make an attack while away from their home in quest of honey, or on their return, until they have entered the hive. It is only in the hive and its vicinity that we expect to meet this irascible temperament, which should not be allowed, or at least may be subdued in a great measure, if not entirely, by doing things in a quiet manner, and, by the use of tobacco smoke. Any person having the care of bees should go armed with this powerful weapon. As bees are not much affected with smoke, while flying in the air, but will have their own way, we must take them in the hive as the place to teach *them* a proper deportment!

Those who are accustomed to smoking will find a pipe or segar very convenient here. But such as are not would do better, perhaps, not to learn a bad habit. I will therefore give a simple substitute.

SMOKER DESCRIBED.

Get a tube of tin about five-eighths of an inch diameter, five or six inches in length; make stoppers of wood to fit both ends, two and a half or three inches long; with your nail-gimlet make a hole through them lengthwise: when put together it should be about ten inches. The ends may be tapered. On one end leave a notch, that it may be held with the teeth, which is the most convenient way, as you will often want to use both hands: it is also always ready, without any trouble to blow through, and also to keep the tobacco burning. When ready to operate, fill the tube

with tobacco, ignite it, and put in the stoppers; by blowing through it you keep the tobacco burning while the smoke issues at the other end.

EFFECT OF TOBACCO SMOKE.

We can now subdue these combative propensities, or render them harmless; turn their anger to submission, and make them yield their treasures to the hands of the spoiler without an effort of resistance! When once overpowered, they seem to lose all knowledge of their strength, and no slave can be more submissive! After the effects of the smoke have passed off, their former animosity will return. Should any resentment be shown on raising a hive, blow in the smoke; they immediately retreat, “begging pardon.” After a few times, they learn “it’s no use,” and allow an inspection. If you wish to take off a box, raise it just enough to blow under the smoke; there is no trouble; you can replace it with another; the bees are kept out of the way with a little more smoke, *and no anger created about it to be remembered*. Those in the box are all submission; they can be carried away and handled as you please, without a possibility of getting them irritated, until they once more get home, and then are much more “amiable” than if the box had been taken without the smoke. They seem to forget, or do not realize anything of the transaction. When bees are to be transferred to a new hive, it is unnecessary to be so very particular about the escape of a single bee; no fears need be entertained of such as get out. In driving, the loud humming indicates their submission; the upper hive can then be safely raised at any time. After being thus driven out, they may be pushed about with impunity, and still be quiet! In short, by using smoke on all occasions where they would be likely to be disturbed without it by our meddling with them, it has a tendency to keep dormant their combative propensities. When these have never been aroused, there is much less danger from their attacks while walking or looking among them. Any one wishing further proof, I would recommend the experiment of managing one year with smoke, and the next without.

Source: Quinby, M. 1853. *Mysteries of Bee-Keeping Explained: Being a Complete Analysis of the Whole Subject*. New York: C. M. Saxton, 279–81.

Bell, Alexander Graham (1847–1922)

Scottish-born scientist, inventor, engineer, and educator Alexander Graham Bell is credited with designing and constructing the first practical telephone.

Bell was born on March 3, 1847, in Edinburgh, Scotland, to Alexander Melville Bell, an expert in phonetics who taught elocution to the deaf through a system dubbed “Visible Speech,” and Eliza Grace Symonds Bell, an accomplished pianist who was herself nearly deaf. He also had two brothers: Melville James Bell (1845–1870) and Edward Charles Bell (1848–1867). His early education consisted of being homeschooled by his mother, followed by three years of formal education—one year in a private school, and two at Edinburgh’s Royal High School. During this time, his aptitude for observation and innovation became apparent. At age 12, he devised a homemade device for quickly husking grain after watching the process in a grain mill while playing with a friend. At age 16, he joined the legacy of his father and grandfather as a “teacher of the deaf”—a title he preferred to be known by—and oversaw his father’s operations in London.

In 1870, the Bell family immigrated to Brantford, Ontario, Canada, after both of Alexander’s brothers died of tuberculosis. At that time, the elder Bell’s Visible Speech system caught the attention of Sarah Fuller, who ran the Boston School for Deaf-Mutes and requested that he apply it to her students. He instead sent Alexander, who moved to Boston in 1871 to apply his father’s system. He found success as a teacher to the deaf and went on to teach at the Clarke School for the Deaf in Northampton, Massachusetts, and the American School for the Deaf in Hartford, Connecticut. While on this circuit, he met his future wife, Mabel Hubbard (1857–1923), a student who had become deaf at age five due to scarlet fever, who was also the daughter of Gardiner Greene Hubbard (1822–1897), cofounder of the Clarke School and Bell’s future financial backer. In 1872, he achieved the position of professor of speech and vocal physiology at the Boston University School of Oratory.

In the early 1870s, Bell began conducting experiments in two-way telegraphy. At the time, the telegraph system was the dominant mode of long-range

communication but was constrained to the dispatch and reception of a single message at a time through a single wire. There was developing fervor to discover a “harmonic telegraph” capable of several messages over several frequencies down a single telegraph wire. Examples from Bell’s contemporaries included Thomas Edison’s (1847–1931) “quadruplex,” which could send 4 messages simultaneously, while Elisha Gray (1835–1901) managed 10. However, all of these laboratory-successful designs proved unreliable in service and thus became practically invalid. Bell received financial backing from Hubbard and businessman Thomas Sanders but soon gained a new ambition: to transmit the human voice across the distance of a telegraph.

Between 1874 and 1875, Bell was joined by electrician Thomas Watson (1854–1934), originally hired to refocus Bell on the aim of his original investment but who soon became the engineering analogue to Bell’s problem-solving ingenuity. Bell’s apparatus was based on the phonautograph, the earliest sound-recording device, and utilized make-break current interrupters driven by vibrating steel reeds or tuning forks. These sent the interrupted current to a distant receiving electromagnet that caused a second reed to vibrate, creating a pattern of vibrations that could be translated into the same voice pattern as transmitted. In the final stages of his experiments, Bell used a water transmitter to conduct the vibrations: the vibration of a diaphragm causes a reed suspended in water—mildly acidified to ensure conductivity—to vibrate, which varies the electrical resistance in the water and causes alternating current in the circuit, translated into voice patterns at the receiver. Bell and his benefactors filed a patent for the apparatus, which was granted on March 7, 1876. Three days later, on March 10, Bell successfully transmitted a full sentence through his apparatus to Watson in an adjacent room, which has been famously recounted in the lab notes and journals of the two scientists as: “Mr. Watson—come here—I want to see you.” According to legend, Bell spoke these words after accidentally spilling a jar of transmitting fluid and called Watson over to help him clean it up, however, it is more likely that the first transmission was entirely planned. Bell had thus succeeded in surpassing the

endeavor for harmonic telegraphy by creating the world's first serviceable telephone.

Bell continued to refine his device for longer distances before demonstrating it publicly for the first time at the Philadelphia Centennial Exhibition, which included such witnesses as Scottish physicist Sir William Thompson and Emperor of Brazil Dom Pedro II. Hubbard assembled the investors necessary to begin the Bell Telephone Company in July 1877, for which Bell acted as technical advisor until his withdrawal from interest in telephony. At the time of the company's founding, Bell married Hubbard's daughter Mabel, and the two would go on to have four children: two elder daughters and two young sons who both died in infancy. Controversy erupted, with numerous claims by competing inventors of their own development of the telephone before Bell. Foremost was Elisha Gray, who claimed that Bell had stolen his idea of using a water transmitter to move the reed/tuning fork in the apparatus. Bell did admit to using the water transmitter for his proof-of-concept experiment but never applied it to public demonstrations or commercial ventures. The Bell Company would face over 550 court challenges over 18 years, some of which reached the Supreme Court of the United States. None were successful. In 1915, Bell inaugurated the first transcontinental telephone call, again to Thomas Watson.

In addition to the telephone, Bell was known to have held around 30 patents: 18 alone, 12 with collaborators. He opened the Volta Laboratory in 1880 to investigate flight. In 1907, he began the Aerial Experiment Association with Glenn Curtis, where he pioneered other inventions: the AEA *Silver Dart* became

the first powered flight in Canada, and he developed the hydrofoil *HD-4* with engineer Casey Baldwin (1882–1948) and Italian inventor Enrico Forlanini (1848–1930), which achieved a world record for its vessel class. Bell used his wealth from the Bell Company to finance the journal *Science* and the National Geographic Society, of which he served as second president after the death of founder and first president Gardiner Hubbard. Bell helped to tailor the society's publication for public accessibility by using illustrations, an unthinkable innovation at the time.

Alexander Graham Bell died on August 2, 1922, at age 75 of complications from diabetes. The entire North American telephone system was shut down in tribute for a full minute during his funeral. The Bell Telephone Company would go on to become the American Telephone and Telegraph Company (AT&T).

Andres Elvira

See also American Telephone and Telegraph Company (AT&T); Edison, Thomas; Phonograph; Wright, Wilbur and Orville; *Vol. 1, Sec. 3: Printing Telegraph*; *Vol. 2, Sec. 3: Curtiss-Wright Aeronautical Engineering Cadettes*; *Vol. 3, Sec. 2: Mobile Phone*

Further Reading

- Casson, Herbert Newton. 2006. *The History of the Telephone*. New York: Cosimo Classics.
- Gray, Charlotte. 2011. *Reluctant Genius: Alexander Graham Bell and the Passion for Invention*. New York: Arcade.
- Grosvenor, Edwin S., and Morgan Wesson. 2016. *Alexander Graham Bell*. n.p.: New Word City.

Primary Document: Letter of Alexander Graham Bell to His Parents Describing His Idea for the Telephone (1874)

In 1874, Alexander Graham Bell was in a race with Elisha Gray to develop and patent an acoustic telegraph—a device to transmit sound, including the human voice, telegraphically. In a letter to his parents, Alexander Melville Bell and Eliza Symonds Bell,

and his sister-in-law, Carrie Bell, written on November 23, 1874, Bell mentions the competition from Gray and the need to obtain a patent; he also describes his idea for the sound transmission apparatus he is developing. Bell asks his parents to save the

letter as a record of his idea and when he had it. Bell's letter is reproduced here.

Salem to Boston
Monday Nov. 23 '74
Dear P. M. & C.

Mr. Hubbard on going down to Washington found that Mr. E. Gray instead of filing a caveat had applied for a patent on his invention—so that a caveat would not protect me from him.

A caveat only protects from those taking a patent after I file the caveat.

Under these circumstances Mr. Hubbard decided not to file mine as it might injure our case by exposing our dates—to Mr. Gray.

He says the only course is to complete our instruments as rapidly as possible and apply for a patent when an interference will be raised between Mr. Gray & myself and then one who can prove priority will obtain the patent.

There is thus no present need of my becoming an American Citizen.

It is a neck and neck race between Mr. Gray and myself who shall complete our apparatus first. He has the advantage over me in being a practical electrician—but I have reason to believe that I am better acquainted with the phenomenon of sound than he is—so that I have an advantage there and I have at hand Prof. Lovering and Mr. Farmer as advisor in every electrical difficulty.

The very opposition seems to nerve me to work and I feel that with the facilities I have now I may succeed.

Portions of my apparatus will be ready for trial tomorrow. However we shall see.

I feel that I shall be seriously ill should I fail in this now I am so thoroughly wrought up.

An idea that I have scarce dared to breathe to anybody for fear of being thought insane I ventured cautiously to open to Mr. Farmer.

To my delight he said the theory was all right but that the difficulties of practically working the idea were such that it would take years to solve the problem practically. He advised me to publish the idea in the Philosophical Magazine after I had protected my telegraphic scheme. The idea to which I allude is an instrument by which the human voice might be telegraphed without the use of a battery at all.

Since the principle of the idea is all right I hope to be able to apply it practically to the telegraphic scheme at once so as to send messages without a battery—substituting instead a permanent magnet.

I shall describe the idea here which led me to think of the plan.

Although the plan has been in my head for a year or so, I never spoke of it so far as I remember as I was uncertain of the fundamental principle. Now that the principle is acknowledged correct I have no doubt the publication of the idea will lead to such an instrument as that I have described.

If you take a permanent magnet and place one of its poles near the pole of an electro-magnet a current of electricity is induced in the coils of the latter. When the permanent magnet is removed from the electro-magnet another current of electricity (of opposite kind to the first) is induced in the coils of the electro-magnet.

These facts have been known for years but the deduction which I have made from them is new. It is this.

If a permanent magnet is made to vibrate in front of the poles of an electro-magnet—an induced oscillating current will be produced in the coils of the electro-magnet. The oscillations of the electrical current will correspond in number and amplitude with the vibrations of the permanent magnet. Hence if we have a harp of steel bars made permanently magnetical arranged over an electro magnet; and if we have the bars tuned to minute intervals of pitch if we talk into one harp certain rods will vibrate with certain amplitudes. Their vibrations will create an electrical vibration in the live wire and will force into vibration the corresponding rods of the other harp.

This is the theory. I can never hope to work it out myself.

Mr. Farmer & Dr. Blake both pronounce it feasible.

Please keep this paper as a record of the conception of the idea in case any one else should at a future time discover that the vibrations of a permanent magnet will induce a vibrating current of electricity in the coils of an electro-magnet.

Fond love
(signed) Aleck

Source: Alexander Graham Bell Family Papers, Library of Congress.

Berliner, Emile (1851–1929)

German-born American inventor, businessman, writer, and philanthropist Emile Berliner is best remembered for inventing the flat disc gramophone or phonograph. The company he founded as Berliner Gramophone engaged in various patent conflicts and disputes over the authorization of sales during its brief history and changed the landscape of sound reproduction, paving the way for the formation of the largest distributor of phonographs in the United States, the Victor Talking Machine Company.

Berliner was born in 1851 into a Jewish mercantile family in the city of Hanover. It was intended for him to follow his father into the mercantile profession, and he graduated from the Samsonschule in nearby Wolfenbüttel in 1865. Berliner became a United States citizen in 1881 and married fellow German immigrant Cora Adler that same year.

Throughout the 1870s, he worked odd jobs in Washington, D.C., and New York while studying and inventing in his private moments. He gained a keen interest in sound reproduction, in particular the workings of telephones and audio recording technologies. Berliner patented a “loose contact” transmitter or an early microphone while a night school student in physics at Manhattan’s Cooper Union Institute for the Advancement of Science and Art. This patent was later sold to Alexander Graham Bell’s American Bell Telephone Company, where Berliner subsequently gained employment from 1877 to 1883. While an employee at Bell Telephone, he patented a type of prefabricated flooring he called “parquet carpet.”

Berliner received his first patent for a gramophone in 1887 after some years experimenting as an independent researcher in Washington, D.C. It proved to be a significant development in the transfer and reproduction of sound. This patent combined the elements of a vibrating needle set within a round, permeable material that could transcribe onto a flat disc made originally of metal. He determined that a flat disc provided an easier and more effective surface for recording when compared to the more prevalent cylinder format. Later on, these master discs would be zinc covered by a thin layer of wax onto which the needle would proceed to scratch and imprint a sound

recording. An acid-treating process rendered the grooves of the recording stable and reproducible.

The 1890s witnessed the development of Berliner’s patents into a business venture. Despite the practical advances he made in developing sound reproduction, Berliner ultimately viewed his invention as a novelty or plaything. Due to patent limitations within the United States, Berliner’s gramophone was initially marketed by a toy manufacturer in Germany to play five-inch discs on a small, hand-operated machine. Berliner gathered investors, and in 1895, he founded the Berliner Gramophone Company, which marketed larger variants of the hand-propelled children’s toy.

The next step in improving his gramophone was the innovation of a motor capable of rotating the turntable consistently while bearing the weight of the reproducer. Berliner sought the collaboration of a machinist and engineer from New Jersey named Eldridge Johnson. Johnson devised and manufactured the wind-up, clockwork motor mechanism for Berliner’s company. He would go on to found the highly successful Victor Talking Machine Company, which controversially claimed Berliner as one of its founders.

Disagreements with Frank Seaman, who was originally granted the rights to market Berliner products in the United States, greatly limited the company’s ability to sell its products to an American audience. The company ceased operations in the United States in 1900 but continued operations in Canada. He received the John Scott (1897), the Elliot Cresson (1913), and the Franklin (1929) Medals from the Franklin Institute for his contributions to American invention.

The remainder of Berliner’s life was dedicated to further developments in the field of acoustics and air flight. In 1926, he patented a ceramic tile for walls to aid in sound amplification. He is also considered an early pioneer of the helicopter. In this capacity, he devised a lightweight rotary engine and developed the use of a vertically mounted tail rotor to counteract torque. Berliner was the president of the Gyro Motor Company, which marketed these aeronautical innovations, from 1909 to 1926. His son Henry Berliner continued research in aeronautics and founded the Berliner Aircraft Company.

Berliner was also an advocate for public health, in particular combating high mortality rates among women and children. He supported safe milk and cleanliness and penned a series of poems geared to children that were collected, illustrated, and published as *Muddy Jim*. He inaugurated the U.S. Bureau of Health Education in 1924. Berliner died in Washington, D.C. on August 3, 1929, from a heart attack.

Sean P. Phillips

See also Phonograph; Vol. 2, Sec. 2: Gramophone/Victrola

Further Reading

Steffen, David J. 2005. *From Edison to Marconi: The First Thirty Years of Recorded Music*. Jefferson, NC: McFarland.

Wile, Frederic William. 1926. *Emile Berliner: Maker of the Microphone*. Indianapolis: Bobbs-Merrill.

Brooklyn Bridge

Designed by John Roebling, whose daughter-in-law, Emily Roebling, finished the job when he could not, the Brooklyn Bridge is located in New York City. Begun in 1869 and completed in 1883, the bridge is considered one of the great American engineering achievements of the 19th century. The bridge spans 486 meters, connecting the cities of New York and Brooklyn. It is the oldest steel cable suspension in the United States. The Brooklyn Bridge took 14 years to complete and, during the construction, at least 20 people died. The bridge cost approximately \$15 million to build. After the grand opening of the bridge, it became an icon of New York City.

The Brooklyn Bridge is a suspension bridge, but it uses a hybrid cable-suspension design that made it unique in its day. It is constructed of granite, limestone, and cement and thousands of steel cables. The bridge's caissons are built with storage compartments in them, famously used to store wine, food commodities, and other non-bridge-related oddities.

Before construction began, John Roebling injured one of his feet, contracted tetanus, and died. The bridge could have not been completed without the

knowledge of his 32-year-old son, Washington A. Roebling, and his wife, Emily Roebling. Washington took over as chief engineer. While working underwater on bridge caissons, Washington contracted decompression disease (the "bends"). Though officially, Washington completed the bridge construction, he only did so because his wife, Emily, took over as unofficial project manager, supervising the daily construction at the bridge site. Washington was forced to watch through a telescope as the bridge was being built. He remained paralyzed for the rest of his life.

Bridge workers earned two dollars a day. They used shovels and dynamite to clear away the mud and boulders from the river before building the two pneumatic caissons, or bridge foundations. This job was risky, as the hot, dense air gave workers headaches and itchy skin, and it also slowed their heartbeats.

The most dangerous part was working underwater in the East River. Workers (including Washington Roebling) rode in small iron containers called "airlocks." After the workers were brought up to the surface, the dissolved gases in their blood were quickly released, a disease called "caisson disease" then and "decompression sickness" or "the bends" now. Decompression sickness caused paralysis, joint pain, numbness, convulsions, speech impediments, and sometimes death. During the construction of the bridge, more than 100 workers were injured and at least 20 killed (the exact number is not known).

The Brooklyn Bridge opened to the public on May 24, 1883, though it was, at the time, called the New York and Brooklyn Bridge or the East River Bridge. President Chester A. Arthur, Mayor Franklin Edson, and Brooklyn Mayor Seth Low attended the bridge opening, as did thousands of New Yorkers. Emily Roebling was present on opening day, though her husband was honored as the bridge manager and she was not. She was the first person to cross the bridge, and today, the bridge carries a plaque in her memory.

On its opening, the Brooklyn Bridge carried the only road that connected Manhattan and Brooklyn. On the first day, a total of 1,800 vehicles and 150,300 people crossed. Six days after the opening of the bridge, there was a stampede off it after a woman fell down the stairs. People doubted the bridge's stability. To eliminate any doubts, circus showman and New York

luminary P. T. Barnum led 21 elephants over the Brooklyn Bridge.

Some engineers doubted the bridge's ability to withstand strong winds. It wasn't until the 1950s, after the collapse of the Tacoma Narrows Bridge, that the engineers decided to test its aerodynamics. They determined that the Brooklyn Bridge could withstand winds because its open truss structure supports the deck, which makes the bridge aerodynamic. Also, John Augustus Roebling accidentally designed the bridge to be six times stronger than he thought it was supposed to be. On the other hand, a contractor, J. Lloyd, discovered that the bridge is not as strong as people thought because cheaper, weaker wire had been used in its construction than intended. To compensate for the low-quality wire, bridge engineers added an additional 250 cables. They also added diagonal cables that were later rendered useless, but they were kept because they help give the bridge its iconic look.

The bridge was renovated between 2010 and 2015 after a bridge collapsed in Minneapolis. The New York City Department of Transportation spent \$508 million to rebuild and widen approach ramps, raise the bridge's clearance, replace rusty barriers, and restripe the road surface. The renovated upper deck supports bicycle and foot traffic, with over 3,500 cyclists and 10,000 pedestrians a week using the deck.

The Brooklyn Bridge became a National Historic Landmark in 1964 and a National Historic Civil Engineering Landmark in 1972. In 1993, on the 100th anniversary of the opening of the bridge, President Ronald Reagan led a formal procession of people walking across it. More recently, in May 2008, there were five days of festivities for the celebration of the 125th anniversary of the Brooklyn's Bridge opening along with a fireworks display. Today, the bridge continues to service New York and Brooklyn, carrying both automobile and foot traffic. The Brooklyn Bridge has become significant to couples who affix "love locks" to the bridge and throw the key into the water to mark their love.

The Brooklyn Bridge stands among the most iconic structures in the United States, along with other great building projects like the Empire State Building and the Golden Gate Bridge.

Peg A. Lamphier

See also Asphalt; Carnegie Steel Mill; Railroad Sleeping Car and Pullman Car; Roebling, Emily; Roebling, John; Steel Arched Bridge; *Vol. 1, Sec. 1: Street Lighting*

Further Reading

Haw, Richard. 2008. *The Brooklyn Bridge: A Cultural History*. New Brunswick, NJ: Rutgers University Press.

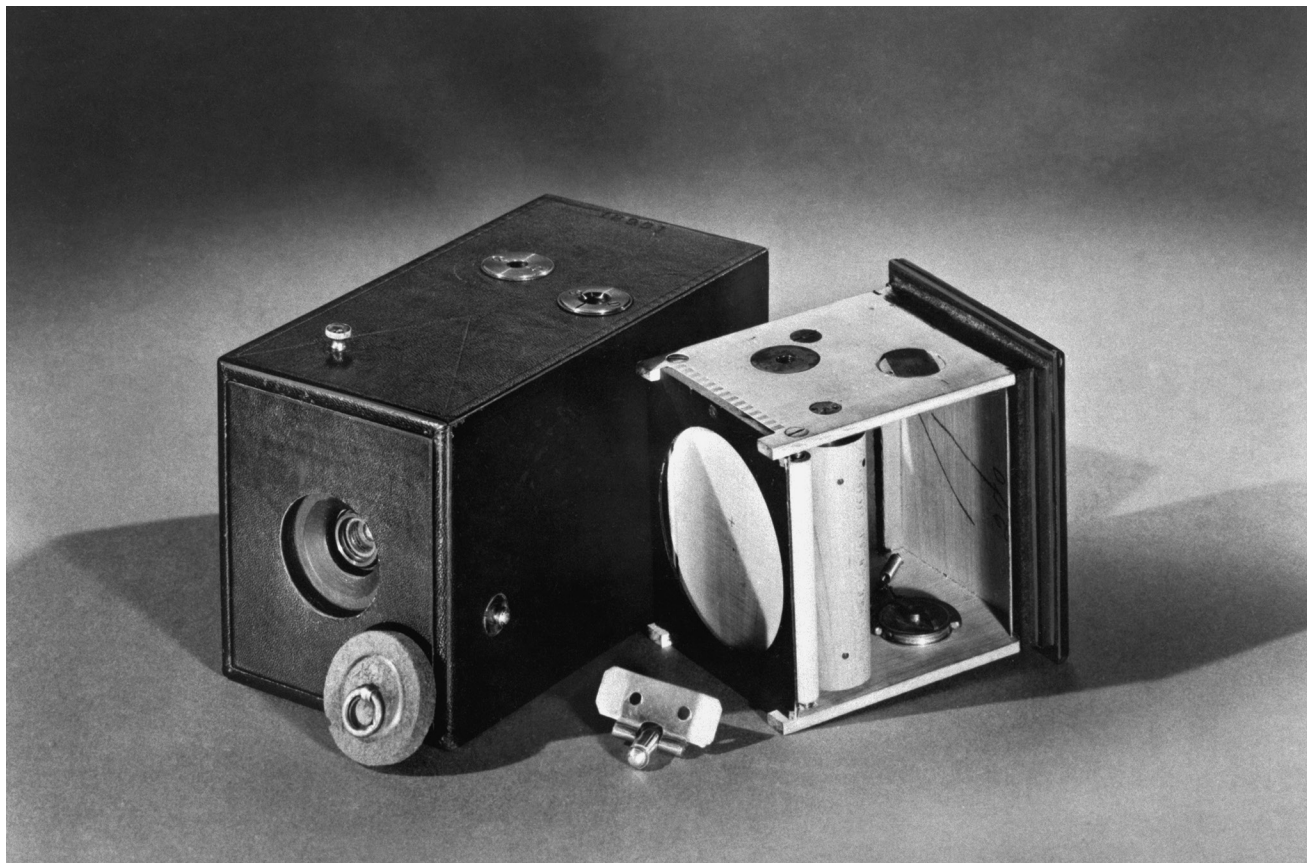
McCullough, David. 2012. *The Great Bridge: The Epic Story of the Building of the Brooklyn Bridge*. New York: Simon and Schuster.

Camera

The camera records light and thus an image, either chemically or electronically. Early cameras were invented during the mid-1820s, with numerous improvements in the 1830s. The first cameras took still pictures, but later cameras also took moving pictures, giving birth to the film industry. The invention of the camera also opened a new world of art. Digital cameras, built into smartphones, are now a part of daily American life.

The term "camera" comes from the light phenomenon called the "camera obscura" (which means "dark chamber"). The invention of the camera came from the study of and experimentation with the camera obscura, in which light rays reflect off a surface: after passing through a pinhole into a darkened room or space, on the wall opposite the pinhole, the light creates a perfect image of what the light is reflecting off of (although upside down). The human eye receives images in a similar way. The camera obscura phenomenon was first observed and experimented with by early philosophers such as Mo Di (470–391 BCE) as is written of in his ancient Chinese text the *Mozì*. Scientists and artists such as Leonardo da Vinci and Johannes Vermeer used the "pinhole camera" to aid them with drawing and painting more proportionally accurate detail in their work.

In 1826, Frenchman Joseph Nicéphore Niépce (1765–1833) captured the oldest surviving photograph using light-sensitive bitumen. Following Niépce's death, his colleague Louis Daguerre (1787–1851)



When George Eastman invented this No. 1 Kodak camera in 1888, it sold for \$25 and was loaded for 100 exposures. The company stopped selling Kodachrome color film in 2009 as customers moved to digital photography. (Bettmann/Getty Images)

continued his work. By 1837, Daguerre had developed the first photographic process, the Daguerreotype, and in 1839 introduced it to the public. As the invention of the camera was improved upon and alternative processes were brought to the public's attention, what was involved in operating a camera became easier and more convenient. Daguerreotype studios came to many cities in the United States only a few years after the device was first announced. For the first time ever, an American could get his or her picture taken. This was in a stark contrast to the difficulty of being painted, which was a lengthy process and only for the wealthy; it also never yielded a fully true-to-life image.

Niépce and Daguerre weren't the only thinkers who hoped that the camera obscura would be another pathway, alongside painting and drawing, to create realistic, lasting images of the real world. To

mechanically capture and preserve the likeness of a sight would be a revolutionary concept that human-kind had never seen the likes of before. Thomas Wedgwood (1771–1805) of England conducted a great many experiments, but the most successful was his work with a silver nitrate coating on white leather. Though his work was groundbreaking and published in many places, all of Wedgwood's images darkened and were lost once exposed to light. This problem wouldn't be solved until a British scientist, William Henry Fox Talbot (1800–1877), used several techniques to stabilize this type of image. Within a year after Daguerre's public announcements, Talbot announced his "salted paper" process called the "calotype" that required a significantly longer exposure time and had less detail but had the capability of reproducing an image after it was captured.

George Eastman (1854–1932) brought photography to the masses with his mass manufacturing of the roll film camera that he referred to as the “Kodak” and patented on September 4, 1888. The low price and capacity to capture 100 exposures made the Kodak take off in popularity. Once used up, the device had to be sent back to the factory for processing and reloading with another roll of film. In 1900, Eastman introduced the world’s most successful and popular camera, the Brownie, with an initial price of a dollar. With its simple-to-use design, the Kodak Brownie and its later models became iconic among the public, with millions and millions sold. It was especially marketed to the young, popularizing amateur photography as a hobby. Many soldiers brought their Brownies along with them to war, and thus, some of the most important war photographs available today were captured on Brownies. George Eastman’s original vision to have photography available to the whole world had finally been accomplished. His slogan, “You press the button, we do the rest,” and his dedication to keeping his camera simple attracted the general public. This made his company wildly successful and made Kodak a leader in camera and film technology and sales.

In 1888, French inventor Louis Le Prince (1841–1890) recorded the first movie, *Roundhay Garden Scene*, on a single-lens, paper-film camera. Before his mysterious and suspicious disappearance in 1890, he had planned to patent his camera. Photography being able to capture motion was groundbreaking and as equally revolutionary as the first cameras. In the 1890s, several furthered such inventions, but the most significant were two French brothers: Auguste Marie Louis Nicolas Lumière (1862–1954) and Louis Jean Lumière (1864–1948). On February 13, 1895, the Lumière brothers patented their three-in-one machine that captured motion pictures, developed the film, and projected the pictures. In the first half of the 1900s, the movie industry took off, and going to the moving pictures became a favorite pastime of many.

In the last quarter of the 1900s, digital photography was slowly invented. Steven Sasson (1950–present), an engineer at Eastman Kodak, made the first digital camera. His prototype weighed eight pounds, took 23 seconds to capture, and recorded its images onto a cassette tape. The late 1980s saw several

companies release their first digital cameras. In 1988, the Fuji DS-1P was released, the first camera to digitally store images. By the 1990s, developments in digital photography were abundant, and Kodak created its photo CD system and developed the first camera made for journalists (sold for \$13,000). Considered the first DSLR (digital single-lens reflex), this professional digital camera system, or DCS, began the digital camera revolution, setting the world onto the gradual path from film cameras to digital ones. DSLR cameras were made for the common person in the early 2000s and, as film cameras became obsolete, Nikon and Canon dominated the digital camera market. High megapixel cameras in smartphones, which have become the people’s favorite camera, build on almost 200 years of invention and have crowned it all with the wonder of sharing your photographs with the world in seconds.

Christian Cobo

See also Eastman, George; Eastman Kodak Company; Edison, Thomas; Kinematoscope; Motion Picture Camera; Photographic Film; Roll Film; *Vol. 3, Sec. 1: Land, Edwin H.; Polaroids; Vol. 3, Sec. 2: Digital Photography; Vol. 3, Sec. 3: Smartphone and 3G Network*

Further Reading

Gustavson, Todd. 2009. *Camera: A History of Photography from Daguerreotype to Digital*. New York: Sterling.

Newhall, Beaumont. 1937. *The History of Photography: From 1839 to the Present*. New York: The Museum of Modern Art.

Can Opener

William Worcester Lyman invented the first rotating can opener in 1870. Lyman was a devoted American inventor from Meriden, Connecticut. His invention was the foundation for can openers that have been in use for almost 100 years.

Previous can openers were basically variations on knives, whereas Lyman’s opener was similar to a beam compass but with a razor on one end. This addition made the can opener much safer and simpler for

everyday use. Lyman's other patents involved improvements to household products like fruit canning jars with hinged lids, tea and coffeepots, hinged butter dishes, and refrigerated pitchers.

Unfortunately, Lyman's version of the can opener required that the can be pierced before it was rotated along the rim, and this inconvenience forced a renovation. In 1925, the Star Can Opener Company in San Francisco, California, improved on Lyman's design. The solution was adding a second, serrated wheel (feed wheel), which allowed a solid grip on the can edge. This innovation was so efficient that it is still in use today. Modern can openers require little maintenance and are quite safe.

Motorized can openers allow for simple and quick opening. Some require only making sure the can is secure and flicking the power switch. But Lyman's introduction of a rotational system gave the foundation for these impeccable systems. William Lyman may not be well known, but he should be, since most of his ideas were the template for many household items that we use today.

Wynton Cooley

See also Curling Iron; *Vol. 1, Sec. 2: Canning Factory*; *Vol. 1, Sec. 3: Twist Drill*; *Vol. 2, Sec. 2: Blender*; Bread Slicer and Wrapping Machine

Further Reading

Deitch, JoAnne. 2001. *Nation of Inventors*. Auburn-dale, MA: History Compass.

Carnegie, Andrew (1836–1919)

Andrew Carnegie, known to modern Americans more for his philanthropy than his business acumen, was an ingenious and innovative businessman whose efforts in building what became U.S. Steel revolutionized the American economic landscape, helping thrust the United States to the forefront of the world's industrial powers. For many Americans, Carnegie's life also became a symbol and a validation of the American experiment, for in his rise from immigrant to tycoon to economic statesman and ultimately philanthropist, Carnegie was seen as embodying the then-popular

concept of the American Dream. Others note that Carnegie's ruthless treatment of workers helped create an industrial system that encouraged unsafe working conditions, long work hours, low wages, and little job security, all in an effort to maximize profit for American industrialists. In this sense, Carnegie is a model for the Gilded Age "robber barons."

Andrew Carnegie was born in Dunfermline, Scotland, on November 25, 1836, one of two sons born to William and Margaret Carnegie. Carnegie's father moved from Dunfermline to Pennsylvania in 1848 after industrialization and mechanization caused the elder Carnegie, a weaver, to lose his job. Settling in Pittsburgh, William Carnegie secured a job in a cotton factory, and Andrew was hired as a bobbin boy. Beginning in 1850, Carnegie worked as a messenger in the city's telegraph office. Ambitious and energetic, Carnegie soon became secretary to Thomas Scott, superintendent of the Pennsylvania Railroad, who was just beginning his highly successful career with the company. Carnegie worked his way up, succeeding Scott as superintendent of the Pittsburgh Division, and when Scott was hired to supervise military transportation for the Union upon the outbreak of the Civil War, he hired Carnegie as his assistant.

His wartime work brought home to him the increasing centrality of the iron industry to the American economy, and in one of the gambles that characterized his business life, Carnegie left the railroad and moved to the Keystone Bridge Company, an operation that replaced wooden bridges with stronger and more durable iron ones. With a foresight that was to characterize his future success, he recognized early on both the developing importance of steel and the tremendous value of the newly developed Bessemer refining system by which iron could be turned into steel. Working off this realization, Carnegie jumped into the developing steel industry, building a new steel plant in the Pittsburgh area, and in no time at all he had become the dominant figure in the industry. He capped his efforts with the founding in 1892 of the Carnegie Steel Company, an enterprise that merged the various individual assets he had accumulated over the years into one vertically integrated corporation. This pioneering approach allowed Carnegie to control each step of the steelmaking process from the mining of the ore to the

production and sale of the finished product. This vertical integration represented a singular advance in both control and efficiency and was an important business innovation.

The company grew, and Carnegie became a theoretical spokesman for an enlightened capitalism, preaching about the rights of workers and the value of unions as a vehicle to protect their jobs. However, his rhetoric did not match up with his reality in 1892, when Carnegie backed his manager, Henry Clay Frick, who had locked out the workers in the bloody Homestead Strike, an event that would forever leave a scar on Carnegie's reputation. Carnegie and Frick spent a lifetime breaking unions and preventing workers from organizing. At the same time, neither the strike nor an economic downturn later in the decade did anything to stop the growth of Carnegie Steel. By 1900, it was producing more steel than was the whole of Great Britain. However, he was tiring of the pressures of business, and when financier J. P. Morgan came to see him about a possible sale and merger that would result in the creation of a huge steel conglomerate, Carnegie was ready to deal, selling his company for \$480 million, a deal that created the world's first billion-dollar corporation—U.S. Steel—and made Carnegie the richest individual in the world.

In the aftermath of the creation of U.S. Steel, Carnegie undertook a second career as a philanthropist. Having often said that “the man who dies rich, dies disgraced,” he was determined to give away most of his fortune. From building hundreds of libraries across the country to supporting numerous colleges and universities, he was an untiring advocate of reading and learning. Critics point out that library building created no meaningful change in the lives of workers who lived in poverty for generations so that Carnegie could become one of the richest men in the world.

Carnegie opposed what he believed was the United States' first foray into imperialism when it acquired the Philippines and Cuba after the Spanish-American War, and in 1910, he formed the Carnegie Endowment for International Peace. One of the earliest proponents of a “league of nations,” he also built a “palace of peace” that would ultimately evolve into the World Court.

In 1886, Carnegie married Louise Whitfield, with whom he had a daughter, Margaret. He died at his summer residence in Lenox, Massachusetts, on August 11, 1919, of bronchial pneumonia. He was cremated, and his remains are interred at the Sleepy Hollow Cemetery in North Tarrytown, New York.

William H. Pruden III

See also Brooklyn Bridge; Carnegie Steel Mill

Further Reading

Livesay, Harold C. 1975. *Andrew Carnegie and the Rise of Big Business*. Boston: Little, Brown.

Nasaw, David. 2007. *Andrew Carnegie*. New York: Penguin Books.

Carnegie Steel Mill

Andrew Carnegie built his first steel mill during the economic downturn known as the Panic of 1873, saving tens of thousands of dollars. Carnegie was a pure capitalist, becoming one of America's wealthiest industrialists through his genius in investing and building industry. He was a pioneer in industrial organization, motivation, and the application of new technology. He proved out the concept of supply chain management through vertical integration.

Carnegie immigrated to America from Scotland as a young boy after the automated loom had destroyed his father's craft as a weaver. Young Andrew started in a Pittsburgh cotton mill, but he rapidly adopted the new technology of the telegraph. He invested in the Pennsylvania Railroad, where he was employed. In 1862, Carnegie then purchased a \$40,000 share in an oil venture known as Columbia Oil, which would return over 400 percent by the end of the decade. Carnegie then searched for a new investment and went to England to study the emerging technology of Bessemer steelmaking. Steel was a new material and stronger than the wrought iron that was used to produce rails for the booming railroad industry. Carnegie saw a huge steel market if the cost of production could be brought down.

Carnegie planned to enter the new steel rail business by being a low-cost and high-technology

producer. First, Carnegie partnered with iron manufacturers and railroad executives to penetrate potential railroad markets. This allowed him to attack the wrought-iron rail market with a steel rail product. In 1875, Carnegie opened the world's largest steel mill and factory to produce steel rails for the railroad. Edgar Thomson Works at Braddock, Pennsylvania (near Pittsburgh), was named after Edgar Thomson of the Pennsylvania Railroad. Carnegie hired the best Bessemer steel engineer in the business, Alexander Holly, to build his new mill. Carnegie had competition in the steel business, but he focused on cost as his competitive advantage.

Carnegie continued to build during the Panic of 1873, saving significantly on construction costs. He hired some of the best and most experienced managers to build his management organization. He brought in railroad men as partners to boost sales. Carnegie and his partners endured the Panic of 1873 to see the mill roll its first rail on September 1, 1875. Carnegie was the first in the industry to apply cost accounting, breaking out the product cost for each process step. Carnegie used this to benchmark and to improve as well as to evaluate new process technology. Carnegie hired young managers by offering them stock and ownership in the company as motivation, based on their performance. These managers, tested in the fire of competition, became the best on the American scene. Over 30 of these young managers would become multimillionaires when Carnegie sold the business. Carnegie boys would go on to control over 40 percent of America's industrial assets.

Carnegie continued to expand and improve the mill, fully integrating the production of steel rails by 1883, using hot blast furnace pig iron produced at the mill rather than buying cold pig iron on the open market. Carnegie built some of the world's largest blast furnaces to drive the process cost down further. Realizing the advantage of vertical integration, Carnegie invested in coke production, using the coal-based fuel for his blast furnaces. Carnegie controlled the partnership and poured his profits into expansion of steel manufacturing versus the diversification that many suggested to him. His managers invented a new type of holding furnaces to allow liquid blast furnace iron to move to the Bessemer converter, further saving on

the cost of reheating. Carnegie instituted a policy of rapid technology implementation to reduce costs throughout the process.

With each improvement in process cost, Carnegie lowered the rail price to take more market share and gain economy of scale. Managers were rewarded with large percentages of cost savings to further motivate process cost reduction. Carnegie further rearranged the rolling operations to eliminate the need for intermediate heating between rolling. His cost push led him to start his own railroad to reduce plant transportation costs. Carnegie expanded the railroad to take iron ore from the Cleveland docks to his Braddock mill. Another part of his vertical integration was the buying of coalfields and coke ovens to produce his own fuel completely. By the 1890s, big railroads such as the Pennsylvania Railroad became the biggest customer of and supplier of services to the steel business. Vertical integration became one of the most successful business models of the Gilded Age. H. J. Heinz applied it in the food business, A. Busch in the beer industry, Henry Ford in auto production, and George Westinghouse in electrical appliances.

Carnegie was one of the first to talk of competitive advantage. He never let his mills lose their technological edge. At his Braddock mill, he perfected the new, clean steel production of open-hearth steelmaking. When he purchased a fairly new Bessemer steel plant at Homestead, Pennsylvania, he gutted it to convert it to the open-hearth process for tougher steel markets. He was the first American manufacturer to apply natural gas as an industrial fuel and the first to electrify his operations. He always maintained a technological edge over the competition, regardless of cost. By the end of the 1890s, Carnegie controlled the rail, structural steel, and armor plate markets.

Besides cost control, technology, and vertical integration, Carnegie mastered competitive advantage by market control. He was a feared competitor. He often targeted competitors, defeating them in the marketplace and taking them over. Carnegie benefited much from the McKinley tariffs, but to his credit, he reinvested in plant equipment and expansion. His one weakness was his poor labor relations. Eventually, Carnegie was bought out voluntarily by J. P. Morgan,

who formed the world's first billion-dollar corporation, U.S. Steel, in 1901.

Quentin R. Skrabec

See also Brooklyn Bridge; *Vol. 2, Sec. 3*: Golden Gate Bridge

Further Reading

Bridge, James Howard. 1903. *The Inside History of Carnegie Steel Company*. New York: Aldine.
 Krass, Peter. 2002. *Carnegie*. New York: Wiley.
 Wall, Joseph Frazier. 1970. *Andrew Carnegie*. Pittsburgh: University of Pittsburgh Press.

Primary Document: Correspondence of Andrew Carnegie and Henry Clay Frick Regarding the Homestead Strike (1892)

While newspapers in the United States and Europe roundly criticized both Andrew Carnegie and Henry Clay Frick, who was chairman of the Carnegie Steel company, for their brutal treatment of strikers at their Homestead Steel plant in 1892, the two men saw breaking the workers, along with their demands for improved wages and working conditions, as a positive good. During and after the strike, Carnegie pretended to be saddened by the whole thing, but, as the letter and telegram exchange here show, Carnegie lied.

May 4, 1892: Letter to Frick

"One thing we are all sure of: No contest will be entered in that will fail. It will be harder this time at Homestead . . . On the other hand, your reputation will shorten it, so that I really do not believe it will be much of a struggle. We all approve of anything you do, not stopping short of approval of a contest. We are with you to the end."

June 10, 1892: Telegram to Frick

"Of course, you will be asked to confer, and I know you will decline all conferences, as you have taken your stand and have nothing more to say . . . Of course you will win, and win easier than you suppose, owing to the present condition of the market."

July 7, 1892: Telegram to Frick

"Cable received. All anxiety gone since you stand firm. Never employ one of these rioters. Let grass grow over works. Must not fail now. You will win easily next trial."

July 17, 1892: Carnegie Letter to Cousin

"Matters at home bad—such a fiasco trying to send guards by Boat and then leaving space between River & fences for the men to get opposite landing and fire. Still we must keep quiet & do all we can to support Frick & those at Seat of War. I have been besieged by interviewing Cables from N York but have not said a word. Silence is best. We shall win, of course, but may have to shut down for months."

November 18, 1892: Telegram from Frick at End of Lockout

"Victory!"

November 21, 1892: Telegram from Frick

"Strike officially declared off yesterday. Our victory is now complete and most gratifying. Do not think we will ever have any serious labor trouble again . . . Let the Amalgamated still exist and hold full sway at other people's mills. That is no concern of ours."

Late November 1892: Telegram to Frick from Italy

"Life is worth living again—Cables received—first happy morning since July—surprising how pretty Italia—congratulate all around—improve works—go ahead—clear track—tariff not in it—shake."

Source: Carnegie, Andrew to Henry Clay Frick, Homestead Strike Correspondence, 1892. http://www.pbs.org/wgbh/amex/carnegie/sfeature/mh_judas.html, accessed August 28, 2018.

Carpet Sweeper

Carpet sweepers are mechanical devices for cleaning carpets. They were popular before the invention of the vacuum cleaner and are still being used today. Melville Reuben Bissell invented the carpet sweeper in 1876.

Bissell conceived of the idea for a carpet sweeper while working in his crockery and glassware shop in Michigan. Glassware and crockery were packed in sawdust, and Bissell wanted something to clean up the messy material. He invented a small box with rolling brushes inside; a handle, like a broom or mop handle, made the device easy to operate. Eventually, friends and customers wondered how they could also own such a cleaning device, and from there, a new business was born. Demand for carpet sweepers was pushed by the increasing affordability of home carpets and the difficulty in keeping them clean.

Bissell started selling carpet sweepers in 1883. When he died in 1889, his wife Anna stepped in to lead the business, becoming the first female CEO in America. She defended and protected the company's patents and marketed sweepers successfully throughout North America and Europe. A decade after taking control of the company, Anna Bissell had transformed her husband's small enterprise into the largest of its type in the world.

Sweepers became popular in the United Kingdom after the first Ewbank (Entwisle and Kenyon Ltd., now Earlex Ltd.) model went on sale in 1889. The Ewbank Carpet sweeper sold extremely well because it was both affordable and efficient. Queen Victoria loved the device so much, she insisted her palace be "Bisselled" every week.

A carpet sweeper is usually composed of a small box whose base is lined with rollers and brushes connected by a belt or gears. The sweeping mechanism works by rolling the base forward, thus using the belt and gears to rotate the brushes. This action allows for detritus to be collected into the removable container. Carpet sweepers frequently have a height adjustment function enabling them to work on different depths of carpet. The remains of the grit and grime can be dumped after use.

Bissell Inc. continues in operation as a private corporation, specializing in vacuum cleaners and related products, including carpet sweepers. New iterations were designed at the turn of the 20th century with rechargeable batteries and electric motor(s) to rotate the rollers and brushes. These new motorized cleaners are more efficient but more tedious because of weight and cords.

The history of carpet sweepers lives on with the floor-cleaning robots that have limited suction power and rely on sweeping to collect larger amounts of debris from the floor. While some newer, more expensive models of robotic vacuums rely only on vacuum motors, some models on the market, such as the Roomba (an autonomous robotic vacuum cleaner) combine suction and sweeping technologies.

Wynton Cooley

See also Can Opener; Curling Iron; *Vol. 1, Sec. 3: Sewing Machine, Automated*; *Vol. 2, Sec. 2: Blender*

Further Reading

Gantz, Carroll. 2012. *The Vacuum Cleaner: A History*. Jefferson, NC: McFarland.

Carver, George Washington (1861–1943)

George Washington Carver is credited with the development of innovative crop rotation methods. To make crop rotation viable, Carver advocated the use of "appropriate technology," an approach that sought to exploit naturally available resources (instead of expensive purchased products). Although Carver worked with many legumes, he achieved fame as the "peanut man" due to the press he received after he testified before the U.S. Congress. By the 1920s, Carver was world famous, had many influential acquaintances, and received many honors as a consequence of his innovations in agriculture.

Carver was born at some time during the American Civil War (1861–1865) on a slave plantation to slave parents in Diamond, Missouri. His mother, Mary, died when he was very young. Although the reason

has remained a mystery, Carver's father was absent. Consequently, Moses and Susan Carver, his owners (guardians after the war), raised him until he was a teenager. Carver was a sickly child, and the Carvers excused him from doing heavy agricultural work. He devoted much of his time to studying and caring for plants. Before long, he developed a reputation as the neighborhood's "plant doctor," even though he could neither read nor write. He left home in 1875 and wandered around in Missouri, Kansas, and Iowa in search of an education. During that time, he supported himself by doing laundry, cooking, and homesteading. After attending classes in a one-room schoolhouse and a high school in Kansas, he enrolled at Simpson College in Indianola, Iowa, in 1890. After a few years, he transferred to Iowa Agricultural College (later Iowa State College), where he earned both a bachelor's (1894) and a master's degree (1896) in agriculture. After graduation, Booker T. Washington (1856–1915), founder of Tuskegee Normal and Industrial Institute for Negroes (later Tuskegee University) in Tuskegee, Alabama, offered Carver a teaching position. Carver accepted Washington's offer. Although Carver had planned to stay at Tuskegee for just a few years and then return to school to pursue a doctorate, he stayed at Tuskegee for the rest of his life. Carver spent most of his career serving in the Tuskegee Agricultural Department in various teaching and administrative capacities.

The primary focus of much of his research had to do with helping farmers in the South make a better living. Due to the high market value of cotton, many farmers were growing it almost exclusively. Since they did not grow enough food crops to survive on, they had become dependent on cotton sale profits and loans. Unfortunately, the planting of cotton in the same fields year after year had depleted the soil of vital minerals and nutrients. Consequently, cotton yields diminished over time, leaving farmers unable to make a profit and deeper in debt. Carver's research showed that nitrate-producing crops such as peanuts and black-eyed peas could return the soil to acceptable growing levels. He assured farmers that they could increase agricultural productivity without the need to purchase

expensive fertilizers if they employed yearly crop rotations with either of these crops. However, if Carver's plan was to work, farmers needed to grow crops that they could both consume and sell. For this reason, Carver developed hundreds of uses for various crops, including peanuts and sweet potatoes.

In a portable school wagon, Carver and his students visited farmers and passed out bulletins that contained ways of transforming crops into numerous edible and marketable cash crops. He showed them how to transform peanuts into more than 100 products, including vegetable oil, cheese, facial cream, ink, soap, wood stain, and butter. Although it took some time, peanut butter became popular by the 1920s. He showed farmers hundreds of uses for sweet potatoes, including transforming them into cereal, coffee, shoe polish, paste, oils, flour, sugar, and bread. In addition, he developed about 60 uses for the pecan. Instead of spending money on food, Carver suggested the consumption of wide weeds, which he called "nature's vegetables." Carver believed that Americans should never go hungry due to nature's inclination to provide the earth with weeds. His bulletins contained many recipes for transforming "wild crops" (including wild onions, wild grass, and wild lettuce) into meals. Without a doubt, these wild creations were an acquired taste, and not very many people opted to consume them unless absolutely necessary. In fact, a few businessmen attempted to capitalize on Carver's recipes, but their businesses went bankrupt. Carver also insisted that farmers could raise more pigs for less money by feeding them acorns that grew wild in the forest instead of expensive cornmeal. Carver also developed many hybrid plants. For example, he developed a hybrid cotton plant to combat the boll weevil. Since the hybrid matured earlier than regular cotton, it could be harvested before the boll weevil had a chance to infest it. He extracted a wide range of dyes from the Alabama clay soil. The dyes were then used to create wood stains and paints.

In 1920, Carver spoke at a convention sponsored by the United Peanut Association of America. Members of the association were impressed with Carver's

speech, and they sponsored an all-expenses-paid trip for him to testify before Congress about the many uses of American peanuts and to ask for a protective tariff. Carver's speech got off to a rough start, as some white politicians were not keen on listening to an African American man. However, Carver's warm disposition and informative presentation won them over. Carver's visit to Congress resulted in a lot of press and gained him worldwide fame. Inventor Thomas Alva Edison (1847–1931) offered Carver a job in his invention factory and offered to pay him a yearly salary that would have exceeded what the U.S. president earned. Carver declined the offer, because he did not want big business ideals to hamper his ability to freely benefit all of humanity. For this same reason, he patented only a few of his hundreds of innovations. Carver received an honorary doctorate, and he was made a member of the British Royal Society of Arts. World leaders, including President Franklin D. Roosevelt (1882–1945), Soviet leader Joseph Stalin (1878–1953), and Indian leader Mohandas Gandhi (1869–1948) sought his advice. He received the Theodore Roosevelt Medal for his distinguished achievements in science.

Carver's accomplishments and fame gave him the opportunity to go on a speaking tour of several all-white colleges. In 1923, the National Association for the Advancement of Colored People (NAACP) awarded him the Spingarn Medal for making a great contribution to the advancement of his race. Carver preferred to devote his time to science rather than politics. During a time of racial segregation, he never took any particular stand against the social order. Unfortunately, all sorts of groups claimed Carver as their role model, and they embellished certain aspects of Carver's life to fit their views. Consequently, the line between truth and myth became blurred regarding some aspects of Carver's life story.

Carver had a gift for making friends. He became a trusted advisor to many of his students. Carver corresponded with cereal manufacturer John Harvey Kellogg for several years. Both men had an interest in the health benefits of certain foods. Carver also struck up friendships with tire manufacturer Harvey

Firestone (1868–1938) and automobile manufacturer Henry Ford (1863–1947). Occasionally, Carver would visit Ford's laboratory in Dearborn, Michigan, and Ford would visit Carver at Tuskegee.

During the last few years of his life, Carver became feeble due to an extended illness. After hearing about his friend's state, Ford sent money so that an elevator could be built in Carver's dormitory. Carver had a well-established reputation for frugality in his personal affairs, which corresponded with his views on wisely using Earth's resources. Even during his fame-making appearance before Congress in 1921, he wore an old, tattered suit. When his acquaintances tried to convince him to buy a new suit for the occasion, he rebuffed them by explaining that Congress was more interested in what he had to say than in how he looked. He told an interviewer in 1917, "Well, someday I will have to leave this world. And when that day comes, I want to feel that my life has been of some service to my fellow man" (Leavitt, 23). He saved most of his meager salary. He never married, and he had no children. When he died on January 5, 1943, he left his life savings of \$33,000 and his estate (worth \$27,000) for the establishment of a research institute for agriculture at Tuskegee. He was buried on the Tuskegee campus beside Booker T. Washington. Ten years after his death, Carver's birthplace was made into a national monument.

Rolando Avila

See also *Vol. 1, Sec. 1: Food Production, Native American; Vol. 3, Sec. 2: Sustainable Agriculture*

Further Reading

- Kremer, Gary R. 1987. *George Washington Carver: In His Own Words*. Columbia: University of Missouri Press.
- Leavitt, Amie Jane. 2008. *What's So Great about . . . ? George Washington Carver*. Hockessin, DE: Mitchell Lane.
- Mackintosh, Barry. 1976. "George Washington Carver: The Making of a Myth." *Journal of Southern History* 42: 507–28.
- McMurry, Linda O. 1994. *George Washington Carver: Scientist and Symbol*. Norwalk, CT: Easton Press.

Primary Document: George Washington Carver Addresses Congress (1921)

In 1921, George Washington Carver appeared before U.S. Congress on behalf of the United Peanut Association of America, an organization founded at the Tuskegee Institute where Carver worked, to promote peanut-based agriculture in the United States. He proposed a tariff on peanuts from other countries to protect American peanut growers. Carver took a number of products with him to his hearing, which he describes in his testimony.

Mr. Carver: Mr. Chairman, I have been asked by the United Peanut Growers' Association to tell you something about the possibility of the peanut and its possible extension. I come from Tuskegee, Ala. I am engaged in agricultural research work, and I have given some attention to the peanut, but not as much as I expect to give . . . I am especially interested in southern crops and their possibilities, and the peanut comes in, I think, for one of the most remarkable crops that we do not already know, and you will also observe that it has possibilities that we are just beginning to find out. If I may have a little space here to put these things down, I should like to exhibit them to you. I am going to just touch a few high places here and there because in 10 minutes you will tell me to stop. This is the crushed cake, which has a great many possibilities. I simply call attention to that. The crushed cake may be used in all sorts of combinations—for flours and meals and breakfast foods and a great many things that I have not time to touch upon right now.

Then we have the hulls, which are ground and made into meal for burnishing tin plate. It has a very important value in that direction, and more of it is going to be used as the tin-plate manufacturers understand its value. Now there is another confection. It is peanuts covered with chocolate. As I passed through Greensboro, S.C., I noticed one of the stores that this was displayed on the market, and, as it understood better, more of it is going to be made up into this form.

B. Carver: Here is a breakfast food. I am very sorry that you can not taste this, so I will taste it for you. [Laughter.]

Now, this is a combination and, by the way, one of the finest breakfast foods that you or anyone else has

ever seen. It is a combination of the sweet potato and the peanut, and if you will pardon a little digression here I will state that the peanut and the sweet potato are twin brothers and can not and should not be separated. They are two of the greatest products that God has ever given us. The can be made into a perfectly balanced ration. If all of the other foodstuffs were destroyed—that is vegetable foodstuffs were destroyed—a perfectly balanced ration with all of the nutriment in it could be made with the sweet potato and the peanut. From the sweet potato we get starches and carbohydrates, and from the peanut we get all the muscle-building properties . . . Here is another breakfast food that has its value. I will not attempt to tell you, because there are several of these breakfast foods that I will not take the time to describe, because I suppose my 10 minutes' time is about up. Of course I had to lose some time in getting these samples out.

Congressman Garner: I think this is very interesting. I think his time should be extended.

Congressman Rainey: The varied use of the peanut is increasing rapidly?

Mr. Carver: Yes, sir. Congressman Rainey: It is an exceedingly valuable product, is it not?

Mr. Carver: We are just beginning to learn the value of the peanut.

Congressman Rainey: Is it not going to be such a valuable product that the more we have of them here the better we are off?

Mr. Carver: Well, that depends. It depends upon the problems that these gentlemen have brought before you.

Mr. Rainey: Could we get too much of them, they being so valuable for stock foods and everything else?

Mr. Carver: Well, of course, we would have to have protection for them. [Laughter.] That is, we could not allow other countries to come in and take our rights away from us. I wish to say here in all sincerity that America produces better peanuts than any other part of the world, as far as I have been able to test them out.

Mr. Rainey: Then we need not fear these inferior peanuts from abroad at all? They would not compete with our better peanuts?

Mr. Carver: Well, you know that is just about like everything else. You know that some people like (margarine) just as well as butter, and some people like lard just as well as butter. So sometimes you have to protect a good thing . . . That is all a tariff means—to put the other fellow out of business. [Laughter.]

Source: United States Congress. House Committee on Ways and Means. *Tariff Information, 1921: Hearings on General Tariff Revision before the Committee on Ways and Means, House of Representatives*. Washington, D.C.: U.S. Government Printing Office, 1921.

Cash Register

James Ritty invented the cash register in 1879 with the help of his brother John. Ritty had struggled with corrupt bartenders before developing a machine that could track the sales of a store. He came up with several variations of the concept, the first of which had a clock-like face and two rows of keys (similar to a typewriter) that tracked the sales. Ritty patented the machine after its second iteration.

A modern aspect of the cash register was added to the third design, which used tabs to display monetary values to both the customer and the clerk. James and John Ritty called it “Ritty’s Incorruptible Cashier.” Sales became public with the fourth iteration, which used paper to track the sales of the day, making a hole at each sales mark. This allowed businesses to count the sales at the end of the day. These early iterations of the cash register pioneered the way for John Patterson, who bought the patent in 1884 and turned the cash register into a worldwide phenomenon, further improving its durability and efficiency. In recent years, cash registers have come to involve newer technologies, including iPads, to account for alternate forms of payment, including credit and debit cards and online payments.

Cassady O’Reilly-Hahn

See also Vol. 3, Sec. 3: Amazon.com; iPod

Further Reading

Bensoussan, Alain, Metin Çakanyildirim, Meng Li, and Suresh Sethi. 2016. “Managing Inventory with Cash Register Information: Sales Recorded but Not Demands.” *Production and Operations Management* 25, no. 1: 9–21.

Friedman, Walter. 1998. “John H. Patterson and the Sales Strategy of the National Cash Register Company, 1884 to 1922.” *The Business History Review* 72, no. 4: 552–84.

Celluloid

Commonly known for its use in photography and films during the early days of both industries, celluloid, a form of fabricated plastic, was invented by John Wesley Hyatt in 1870. It consists of a thin, transparent plastic that was also flammable; acetate safety film replaced it in the early 1950s, but the name “celluloid” stuck and is still used in phrases such as “Celluloid Heroes,” a song popularized by the Kinks. Despite its permanent connection with the movies, celluloid plastic was also used for a variety of inexpensive items such as knife handles, holiday decorations, razors, and hair ornaments.

Hyatt created celluloid by mixing a main base of cellulose with variously colored pigments, fillers, camphor, and alcohol. The inventor and industrialist was previously known for the creation of the first artificial plastic. Hyatt worked on a replacement for ivory billiard balls; however, none of his experiments were successful. He eventually found a plastic material that could be made by mixing nitrocellulose with alcohol and camphor. Nitrocellulose is composed of a flammable nitrate of cellulose from wood or cotton. Hyatt paired up with his brother Isaiah Hyatt and patented their pale yellow film with brown ridges on the edge as “celluloid.”

The brothers established the Celluloid Manufacturing Company and moved from Albany, New York, to Newark, New Jersey, where John Hyatt came up with

many other inventions—such as roller bearings, sugarcane mills, and sewing machines. In the 1870s, photographer John Carbutt contracted with the company to make celluloid strips coated with photosensitive gelatin. Early experiments by Thomas Edison in motion pictures used this version of celluloid. In 1889, Eastman Kodak applied for patents on a flexible photographic celluloid that gave birth to the motion picture industry.

Celluloid is rarely used in the 21st century, both because of the digital revolution and because other, more durable and less flammable products have replaced it. Only two celluloid factories, both in China, remain in the world.

Rosanne Welch

See also Camera; Photographic Film; *Vol. 1, Sec. 3: Sewing Machine, Automated*; *Vol. 2, Sec. 2: Talking Movies*; *Vol. 3, Sec. 1: Plastics*

Further Reading

Winston, Wheeler, and Gwendolyn Audrey Foster. 2013. *A Short History of Film*. New Brunswick, NJ: Rutgers University Press.

Coca-Cola

Coca-Cola is an American soft drink introduced to the public in 1886. In its infancy, it was promoted as a beverage with medicinal properties. As America's favorite soft drink for a good portion of the 20th century, Coca-Cola has expanded its reach throughout the world. In 2012, it was designated as the most valuable global brand.

In 1886, John “Doc” Pemberton invented the beverage in Atlanta, Georgia, after experimenting with various combinations of ingredients to make a drink that was tasty and had medicinal value. Pemberton was a pharmacist who believed in the use of natural ingredients such as herbs, plants, and vegetables to help heal illnesses and diseases. Although skilled in conjuring up concoctions, Pemberton was a poor businessman. He never repaid loans and was always on the lookout for new capital and potential partners. He found three men who were willing to put up money and join in partnership. In January 1886, he formed a



This magazine advertisement for Coca-Cola, ca. 1890, shows the popularity of the product invented in 1866 by John Pemberton, an American pharmacist. (Library of Congress)

company with Ed Holland, Frank Robinson, and David Doe, and the Pemberton Chemical Company was incorporated. The goal was to create the perfect drink that they could sell at an affordable price.

Thinking that Atlanta natives would want something to drink during the scorching hot summers besides tea and coffee, Pemberton first determined to develop a sweet and syrupy beverage with caffeine extracted from African kola nuts. However, he discovered that the caffeine from the liquid extraction was extremely bitter and not drinkable. Through trial and error, he found that if he put in a drop of the liquid extraction and added synthetic caffeine instead, the taste was palatable. The man-made caffeine was still bitter although not as strong as the original liquid extraction. Then, Pemberton sought to disguise the bitterness of both types of caffeine by making the beverage exceedingly sweet.

Other Coca-Cola ingredients included sugar, caramel (or burnt sugar, which gave the drink its dark amber color), lime juice, citric acid, and phosphoric acid. For flavoring, he included vanilla extract, elixir of orange, and oils from fruit, herbs, and trees such as lemon, nutmeg, spicebush, coriander, and neroli (a fragrant, pale yellow essential oil from orange blossoms), and cassia (a dried, rough bark from trees found in Asian tropical regions). Last, Pemberton added last cocaine to the drink, which had been extracted from the coca leaf in liquefied form. At the time, cocaine was viewed as a wonder drug, and Pemberton thought that when he combined it with the caffeine, his resulting drink would make people feel happy, alert, and well. The final mixture was a thick syrup that could be sold to soda fountains; Coca-Cola drinks were made by combining the syrup with carbonated water.

One of the partners, Robinson, chose the name Coca-Cola. In June 1887, Pemberton received a patent. For testing, he had samples brought to Willis Venable Soda Fountain located three blocks away in Jacob's Pharmacy. For marketing, Robinson worked on fine-tuning the logo design with an engraver. He had coupons printed with an offer of two free samples per person that were mailed out to a portion of Atlanta's population. Posters, streetcar signs, and oilcloth banners for soda fountains were also created. A salesman was hired as well to travel to other cities in the South. Sales picked up modestly with these efforts.

Not long after, Pemberton became sick. He sold the company to Venable, who didn't have any money. Pemberton's friend George Lowndes agreed to put some up, and the contract they signed stipulated that Venable would be Lowndes's partner and each man would own a third of the rights to the product. When Robinson, one of Pemberton's original partners, discovered the deal, he tried to sue Pemberton, but to no avail. Pemberton was penniless and died shortly after giving up control of his company.

Robinson's luck changed when he encountered Asa Candler, a successful pharmacist and drugstore owner who had hired Robinson as a part-time bookkeeper. In 1888, Robinson saw an opportunity to buy back Coca-Cola when Venable violated the contract, and Lowndes decided to sell his two-thirds of the shares. Robinson convinced Candler to buy the

company. He acquired full ownership of Coca-Cola and put Robinson in charge. In 1891, Candler decided to get out of the pharmacy business to devote himself full time to Coca-Cola. The men decided to refine the formula, in part because the Coca-Cola syrup turned rancid when the phosphoric acid in it interacted with the tin of metal cans. Glycerin was then used as a preservative and proved to be a stabilizing agent.

At the same time, the company altered the amounts of both coca leaf and kola nut extractions in response to a national debate about the negative effects of cocaine and caffeine. The company began bottling Coca-Cola in 1891 and in 1915 introduced the iconic "hobble-skirt bottle" design. Robert W. Woodruff assumed the presidency of Coca-Cola in 1923, and he expanded the soft drink's appeal to Europe, Asia, and parts of Africa. Under his leadership, Coca-Cola continued to thrive and became the product that was recognized worldwide. The company first canned its beverage in 1955.

Through his leadership, Coca-Cola has maintained its dominance in the beverage industry for almost a century, with the notable exception of the "New Coke" imbroglio of 1985. That's when the company changed the formula, tested it, and found that consumers preferred the new version. Yet, when the company introduced New Coke to consumers, the public reacted negatively, creating a firestorm of controversy. Coca-Cola returned to its old formula within three months of New Coke's debut.

As carbonated drink competition rose and demand for high-calorie drinks fell in the late 20th and early 21st centuries, Coke lost its market dominance. But there can be little doubt that Coca-Cola continues to be a major part of the global economic marketplace.

Marilyn Chin

See also Soda Fountain; *Vol. 1, Sec. 2: Canning Factory*

Further Reading

- Allen, Frederick. 1994. *Secret Formula: How Brilliant Marketing and Relentless Salesmanship Made Coca-Cola the Best-Known Product in the World*. New York: Harpers Business.
- Elmore, Bartow J. 2015. *Citizen Coke: The Making of Coca-Cola Capitalism*. New York: W. W. Norton.

Cotton Candy Machine

The cotton candy machine was invented in 1897 by William J. Morrison and John C. Wharton. Machine-spun sugar gained wide popularity when it was served at the 1904 World's Fair in Missouri as "fairy floss."

Although the electric cotton candy machine dates to the turn of the 20th century, cotton candy's roots can be traced to centuries earlier. Previously, spun sugar had been a treat reserved for the wealthy aristocracy and was largely used as decoration for desserts and not as a singular confection. Records from as early as the 15th century as well as everyday cookbooks from the 18th century include recipes for the sweet; however, the process was complex as well as time- and labor-intensive.

Morrison (1860–1926), the better known of the two inventors, was both a dentist in Nashville, Tennessee, and a children's book author, and he held a multitude of other patents, including for a process for extracting oil from cottonseed, as well as being credited for the first water purification plant in his hometown. He attended the University of Tennessee Dental College and became president of the Tennessee State Dental Association. However, his most widely known contribution is as the coinventor of the electric cotton candy machine. Along with the confectioner John Wharton, also of Nashville, they invented and patented a candy machine (patent number US618428 A, filed on December 23, 1897) that worked very much like modern ones. Even though many sources attribute the electric cotton candy machine to Morrison and Wharton, their original patent did not specify that the design could operate solely or predominantly on electric power; rather, the machine utilized "foot-power," although they specified that any source of power could be used without changing the overall mechanics of the invention.

The machine itself consisted of a metal bowl that contained a central spinning head perforated with very small holes. The machine melted sugar, and forced air would push it through the perforations. Cotton candy, or "fairy floss," as it was then known, is the equivalent of sugar glass. The sugar syrup instantly crystallizes into long, thin strands, creating a delicate confection that is mostly air. The cotton candy machine allowed Morrison and Wharton to produce a treat similar to spun sugar but much more ephemeral, silk-like, and

delicate as well as to do so more cheaply and quickly. The cotton candy machine also resulted in the now well-known cloud texture, while the earlier spun sugar's strands were unformed and more distinct.

Morrison and Wharton introduced their cotton candy-making invention to the public at the St. Louis World's Fair of 1904. Their "fairy floss" is reported to have delighted fairgoers, with nearly 70,000 helpings sold during the fair's six-month duration. In fact, the cotton candy machine was such a hit that it took home the prize for "Novelty of Invention." In the 1920s, another dentist, Josef Lascaux, attempted to improve Morrison and Wharton's design, but his invention was not nearly as popular, successful, or arguably improved. However, it was Lascaux who coined the term "cotton candy," and that is the name that has been used in the United States ever since, although the treat is still known as "fairy floss" or "candy floss" in other countries.

Cotton candy remains a staple at state and county fairs and carnivals, and many companies package and sell it commercially. There are even machines for making cotton candy in one's home. Both flavorings and colorings can be added to produce a multitude of colors and flavors, but cotton candy is produced in exactly the same way as it was originally. Numerous patents have been filed for improvements on Morrison and Wharton's original mechanism, generally by candy-making companies, to make cotton candy easier to mass-produce commercially.

Stefka Tzanova

See also Coca-Cola; *Vol. 2, Sec. 2: Life Savers Candy*

Further Reading

Christen, Arden G., and Joan A. Christen. 2005. "William J. Morrison (1860–1926): Co-Inventor of the Cotton Candy Machine." *Journal of the History of Dentistry* 53, no. 2: 51–56.

Crayons

The Crayola crayon, an iconic staple of American youth, first appeared in 1903 thanks to the inventive minds of Edwin Binney and C. Harold Smith. The crayon is a colored wax stick used for drawing and other art. Though Crayola crayons are the most famous

and iconic crayons, many companies make crayons out of wax, charcoal, and chalk.

Cousins Edwin and Harold first began working together as salesmen in 1880 under Edwin's father, Joseph Binney, at his company, Peekskill Chemical Works, in Peekskill, New York. After Edwin's father retired in 1885, Edwin and Harold formed a new partnership and renamed the company Binney & Smith. Having grown up together, the partners developed and maintained a strong working and personal relationship, a true asset to the success of their company. They even alternated being its president and vice president. Smith's outgoing personality served him as the lead salesman. Binney's quiet and thoughtful demeanor made him a successful businessman. Binney & Smith emphasized listening and responding to consumer needs, a habit and value that in turn sparked their notable contribution to American society.

Before making their defining invention, Binney and Smith produced red oxides, used in paint, and carbon black. After numerous requests from schoolteachers, the duo created the first dustless school chalk called "An-Du-Septic Dustless Blackboard Chalk" in 1902. With schools becoming Binney & Smith's largest client, the team shifted focus to create a safe, clean, non-toxic and affordable crayon to market to classrooms. In 1903, the eight-pack of Crayola crayons appeared, featuring red, orange, yellow, green, blue, violet, brown, and black, priced at a nickel a carton. Credit for the name "Crayola" goes to Edwin's wife, Alice, who combined the French word "*craie*," meaning "chalk," with "-ola" from "oleaginous," meaning "oily." Initially, schools could not afford the Crayola product, so the U.S. government became the first patron of the boxed crayons, distributing them to Indian reservations.

Despite the passing of the innovative duo, Smith in 1931 and Binney in 1934, the Crayola company continued its success. Expanding upon the relationship between Crayola and the school systems, the company created a teacher-training workshop in 1948 to demonstrate the many ways in which teachers could utilize Crayola products in their classrooms. Shortly after the launch of that orientation program, Crayola released the 48-crayon box displaying the notable "stadium seating" design. Ten years later, the even more notable 64-crayon box with a built-in sharpener

appeared in stores. While the success of the Crayola crayon and other Crayola products continued to evolve over the decades, in 1984, Binney & Smith became a subsidiary of Hallmark, who still has ownership today. Just shy of a decade after Hallmark purchased the company, Crayola celebrated its 90th birthday by introducing 16 new colors to the existing ones, selling them in a 96-count crayon box.

Creating the Crayola crayon requires a detailed process. Liquefied paraffin (wax) is pumped from storage tanks to vats and mixed with powdered pigment for color and talc for texture and to bind all the components together. The vats of material are heated to 240°F and then transferred to a 40-pound bucket. From the bucket, contents spill in controlled quantities onto a table of molds, where the mixture settles into its crayon-shaped divots and cools. After about seven minutes, a machine cuts away excess wax, and the crayons are pushed from the mold to a tray where workers inspect each crayon by hand, discarding any that are below quality standards. Approved crayons move down the assembly line to be wrapped with the Crayola label and then packaged.

Since the basic eight of 1903, more than 600 variations of Crayola crayons have been created. Over 3 billion crayons are produced annually at the Binney & Smith plant in Easton, Pennsylvania. The Crayola crayon tethers generations to nostalgic childhood memories while building the creative minds of future generations. In fact, a study conducted at Yale University ranks the smell of the Crayola crayon at 18 out of 20 of the most identifiable scents among American adults, solidifying the effect that this company and its product has on our society.

Rebecca Morello

See also Cotton Candy Machine; Paper Clip; *Vol. 2, Sec. 2: Binney & Smith Inc.*

Further Reading

Py-Lieberman, B. 1999. "The Colors of Childhood." *Smithsonian Magazine*. <http://www.smithsonianmag.com/history/the-colors-of-childhood-36067809/?page=1>, accessed August 28, 2018.

Slater, L. 2016. *Crayola Creators: Edward Binney and C. Harold Smith*. Minneapolis: Abdo.

Curling Iron

A curling iron is a rod-shaped instrument that uses heat to curl hair. Curling irons are made of a variety of materials, including Teflon, metal, and titanium. The shape of the rod can be cylindrical, conical, or that of a reverse cone. Types of curling irons include Marcel; spring-loaded; and clipless, handled irons. The Marcel handle requires pressure to be applied to the clamp; however, the handle of the spring-loaded style does not require pressure. Hair is curled around the rod on a clipless handle version.

Historians are unsure who invented the first curling iron, as they date back to 2000 BC. American-born inventor Hiram Maxim obtained the first patent for one in 1866, improving the design. He also invented the Maxim Gun, a portable, fully automatic machine gun, and an amusement ride that he called “the Captive Flying Machine.” Maxim claimed to have invented the lightbulb, though Thomas Edison filed the first lightbulb patent in 1878.

The curling iron has evolved and been redesigned throughout the years. In 1959, Roger Lemoine and Rene Lelievre invented the electric curling iron that is widely used today.

Tracy Liu

See also Edison, Thomas; Electric Iron; Electric Lightbulb; Ironing Board

Further Reading

Dyer, Joyce, et al. 2016. *From Curlers to Chainsaws: Women and Their Machines*. East Lansing: Michigan State University Press.

Syprett, Comer, and Grace Doran. 2010. *Mystery of Hair Styling: Vintage Cutting, Finger Waving, Curling and Setting Techniques for 1950s Retro Styles*. n.p.: Bramcost.

Diner (Horse-Drawn)

Walter Scott (1841–1924) is credited with creating the first late-night eatery on the eastern coast of America with quick, walk-up service—the precursor to the all-night American diner and even today’s food trucks. The inception of this unique café experience began inauspiciously out of a wooden, two-wheeled

pushcart. Born out of a need for late-night, inexpensive, homemade hot meals, Scott’s lunch cart’s defining difference from restaurants of the period was mobility and service to an after-hours clientele. Over time, the evolution of the lunch cart to stationary diner was from pushcart to horse-drawn wagon to a manufactured structure built off-site and then delivered to and assembled at a permanent location.

Scott was born in Providence, Rhode Island, to Juliet Howland Scott and Joseph A. Scott on November 28, 1841. After the death of Scott’s father, the enterprising young man took to the streets as a pushcart vendor to financially aid his widowed mother. With the outbreak of the American Civil War, Scott tried unsuccessfully to enlist and then tried his hand at farming in New Jersey—but with no success. At that time, pushcarts sold raw foods such as fruits and vegetables but could not offer heated products or full entrées.

Returning to Rhode Island, Scott secured a job at the *Providence Evening Press* and the *Morning Star* newspapers. Working late into the night, Scott keenly felt the lack of available meals for him and his fellow newspapermen. Restaurants of the era closed after the supper hour, leaving a late-night community fending for themselves. Returning to his street vendor roots, Scott built a pushcart and began selling premade sandwiches and hot coffee out of his specially designed wooden cart. Street vendors were not unusual in that era, but mobile, after-hours meal service was. Innovative for its time, demand for it increased, and he left the newspaper business behind to pursue his mobile food venture full time.

By 1872, Scott’s enterprise had expanded to include a horse-drawn wagon. He redesigned a freight wagon, adding a roof, four walls, and a door. Inside, he created a kitchen workspace with countertops and storage. With Scott inside the wagon, he took orders, cashiered, and served through two open windows. With his newly designed food wagon, Scott guided its horse through the streets of Providence late at night, catering to neighborhoods where restaurants had closed for the evening, providing hot food for an all-night crowd of factory workers, newspapermen, and after-hour bar- and theatergoers.

With Scott’s innovation, customers lined up at his window, placed their orders, paid for them, and received their meals. Thirty cents would buy a plate of

chicken, and a nickel would buy a hot sandwich made from fresh-baked bread or a large slice of huckleberry, apple, or mince pie. As his business grew, Scott expanded his menu to include a variety of sandwiches made with egg, ham, or chicken; pies; beans; hot dogs; and hard-boiled eggs. By 1887, his hometown newspaper, the *Providence Journal*, reported Scott as “the Veteran Lunch man.”

Scott’s idea caught on throughout the region. With increased competition by other entrepreneurs came further innovations and variations. Competitors began offering an enclosed dining experience, complete with kitchen and seating for customers, all housed inside an enclosed, mobile wagon.

The manufacturing of commercial lunch wagons had begun, and by 1898, the United States Lunch Wagon Company operated wagons in 25 cities. By the time of Scott’s retirement in 1917, lunch wagons had so proliferated that city ordinances began regulating the now-aging food wagons, limiting their presence to the time from dusk until dawn. To circumvent city regulations, industrious lunch wagon owners found semi-permanent, off-street locations for their wagons and thus were able to operate around the clock. Referred to as “lunch cars,” “dining cars” or “night lunch wagons,” their popularity continued to grow, and by 1924, they became known as diners, evolving into the iconic American diner experience we know today.

Cynthia J. Parker

See also Dishwashing Machine; *Vol. 1, Sec. 3: Conestoga Wagon*; *Vol. 2, Sec. 2: Chuck Wagon*

Further Reading

Gutman, Richard J. S. 1990. *American Diner: Then and Now*. Baltimore: The Johns Hopkins University Press.

Kirby, Richard Shelton, Sidney Withington, Arthur Burr Darling, and Frederick Gridley Kilgour. 1990. *Engineering in History*. New York: Dover.

Dishwashing Machine

Josephine Cochrane was the inventor of the first commercially successful dishwashing machine, which used water pressure instead of scrubbers to clean

dishes. She received a patent for the device on December 28, 1886. Her company, Cochrane’s Crescent Washing Machine Company, is now part of Whirlpool Corporation.

Cochrane was born in Shelbyville, Illinois, to John Garis, a civil engineer, and Irene Fitch Garis. Her maternal grandfather, John Fitch, was an inventor who was awarded a steamboat patent. She married William Cochran (Josephine added the “e” to their name) on October 13, 1858. He became a prosperous dry goods merchant and local politician. The pair threw many parties, and Cochrane soon became frustrated with the servants, who mishandled the family’s heirloom dishes. Realizing that washing the dishes herself was tedious, Cochrane dreamed of a machine that used water jets to do the job. William’s death, in 1833, left Cochrane heavily in debt, motivating her to turn her dream into a reality.

The first patent for a dishwashing machine was issued to Joel Houghton in 1850, for a wooden machine with a hand-turned wheel that splashed water on dishes. In the 1860s, L. A. Alexander added a geared mechanism that allowed a user to spin a rack of dishes through a tub of water. Neither of these devices was particularly effective or commercially viable. Cochrane built her prototype in a shed behind her home with help from George Butters, a local mechanic employed by the Illinois Central Railroad. She constructed wire compartments to hold plates, cups, and saucers. These compartments were placed inside a wheel that lay flat inside a larger copper boiler. A motor turned the wheel and pumped hot, soapy water over the dishes.

Cochrane received her first patent on the Garis-Cochran Dish-Washing Machine in 1886. She established the Cochrane’s Crescent Washing Machine Company, and her first customers were primarily restaurants and hotels. Housewives were less interested in the machine for a number of reasons; some women enjoyed washing dishes by hand and felt they did not need the machine. Cochrane’s dishwasher also required a great deal of hot water, and many homes did not have hot water heaters large enough to supply the machine.

In 1893, Cochrane convinced restaurants at the World’s Columbian Exposition in Chicago to use her

invention, and her dishwasher was exhibited in Machinery Hall, where it won a prize for design and durability. She soon had enough business to open her own factory in an abandoned schoolhouse, and her client list grew to include hospitals and colleges. Homemakers would eventually embrace the dishwasher but not until the mid-20th century. Cochrane was still personally selling her machines until shortly before her death in 1913. In 1916, Hobart bought Cochrane's and changed its name to that of the KitchenAid brand. Hobart and KitchenAid are now part of Whirlpool Corporation.

Kathleen Barker

See also Carpet Sweeper; Rotary Washing Machine; *Vol. 1, Sec. 3: Electric Stove*

Further Reading

Sobey, Ed. 2010. *The Way Kitchens Work: The Science behind the Microwave, Teflon Pan, Garbage Disposal and More*. Chicago: Chicago Review Press.

Dow Chemical Company

The Dow Chemical Company (Dow) sells more than 2,000 different products, including chemicals and plastics. Dow survived early challenges due to the founder's vision, perseverance, and innovation. Both world wars created opportunities for Dow to grow and expand its product line. In spite of controversies surrounding weapon sales, health issues, pollution, and tax evasion charges, Dow has continued to grow and produce innovative products.

Herbert Henry Dow (1866–1930) founded Canton Chemical, his first company, in 1890. While several companies exclusively extracted bromine (for salt) from brine in underground reservoirs, Dow was interested in extracting other chemicals as well. After Canton Chemical went bankrupt, he founded Dow in 1897. At a time when many people still viewed the electric lightbulb as a novelty, Dow's use of electric current to extract bromides from brine was innovative. Dow produced bleaching agents from bromides, which it sold to Kodak (a photography company founded in 1888).

In 1900, Dow grew due to a merger with Midland Chemical Company. The larger Dow then began to sell bromides in Europe. However, a group of European bromide producers banded together in a price war to try to push Dow out of business. The German-British cartel sold its product in the United States at \$.88 a pound (below cost). The only way that Dow could make a profit was by selling its product at no lower than \$1.65 a pound. Many U.S. bromide-producing companies closed during the price war. However, Dow helped his company survive during these difficult economic times by purchasing imported bromide in New York at cartel-set, below-cost prices and then selling it in Europe (where the price was still \$1.65 a pound).

Although Germany still dominated the world chemical market, during World War I (1914–1918), German chemical producers stopped selling their products to the United States. Consequently, Dow (and a handful of other U.S. chemical producers) supplied U.S. industry with needed products. The need for various wartime supplies also encouraged U.S. companies to expand their product lines. Dow began making phenol (for explosives) and magnesium (for incendiary devices). Later uses of Phenol included the manufacture of plastics, antiseptics, and disinfectants. One of the most important later applications of magnesium was in the manufacture of light alloys for the aerospace industry.

After the war, the U.S. Congress protected U.S. chemical makers by imposing tariffs. Dow's yearly sales climbed from \$4 million in 1920 to \$15 million by 1930. After Dow's death in 1930, his son Willard ran the company. In later years, Dow began extracting bromine from seawater (1933), entered the plastics business (1935), and expanded internationally with the establishment of Dow Chemical Canada, Ltd (1942). In 1943, Dow and Corning Glass merged to form the Dow Corning Company, which specialized in silicone products.

After World War II (1939–1945), Dow expanded its research and development to include more household-type products. In 1947, Dow became a corporation (a public company that trades its shares on a stock exchange). Willard died in a plane crash in 1949, and Lee Doan (his brother-in-law) took over operation of the company. That year, Dow's yearly sales were \$200

million. Under Doan's leadership, Dow's yearly sales quadrupled within a 10-year period. In 1952, Dow expanded outside of North America with the establishment of Ashai-Dow in Japan. The next year, Saran Wrap (a thin and clingy plastic for wrapping food) became a household product and transformed Dow into a high-profile company.

In 1964, Dow exceeded \$1 billion in annual sales, and in 1968, Ziploc bag technology (reusable and resealable zippered bags mostly used for food storage) was test-marketed and later sold to S. C. Johnson & Son. During the Vietnam conflict (1955–1975), Dow produced napalm (a highly sticky and flammable jelly used in bombs and flamethrowers) and Agent Orange (a chemical defoliant). By the mid-1960s, college students protested against Dow's involvement in the war. Some Dow representatives defended the company by arguing that Dow had no control over U.S. foreign policy. At the same time, other representatives argued that U.S. troops should have weapons that the Pentagon believed to be necessary. After the war, Dow executives sought to erase the stigma associated with civilian Vietnamese casualties and to reestablish a consumer-friendly image.

However, Dow was plagued by concerns over public health issues, environmental damages, and charges of tax fraud. In the 1980s, Dow faced public scrutiny with high-profile lawsuits filed by many women who claimed that the company's silicone breast implants caused autoimmune disease and cancer. Although Dow settlements with breast implant recipients totaled more than \$3 billion, over 20 independent studies found no causal relationship between silicone and these illnesses. In 1972, Dow introduced Lorsban, an insecticide, but it was banned by the Environmental Protection Agency (EPA) in 2000. After decades of study, the EPA had concluded that the widely used product could cause brain and nervous system damage to young children. In 2003, Dow reached an agreement with the EPA to clean up several contaminated waterways and paid millions of dollars for other pesticide-related damages. In 2013, a U.S. federal judge found Dow guilty of tax evasion. Although Dow appealed the ruling, a higher court rejected the appeal.

Between the late 1980s and the early 2000s, Dow merged with several other companies. In 2001, Dow surpassed DuPont as the largest chemical company in the United States. By this time, Dow had 50,000 employees and annual sales of \$27.8 billion. After some restructuring, DowDuPont (the world's largest chemical company) was created with the merger of Dow and DuPont in 2017. According to the company's business philosophy, the chemical industry "still has vast potential for technological advancement, as it works to identify and solve problems facing the world."

Rolando Avila

See also DuPont Company; Eastman Kodak Company; *Vol. 3, Sec. 1: Silent Spring*

Further Reading

Dow. "Innovation." <http://www.dow.com/en-us/about-dow/public-policy/global/innovation>, accessed August 28, 2018.

Duerksen, Christopher J. 1982. *Dow vs. California: A Turning Point in the Envirobusiness Struggle*. Washington, D.C.: Conservation Foundation.

Poland, Alan Blair. 1980. *A History of the Dow Chemical Company*. Ann Arbor, MI: University Microfilms.

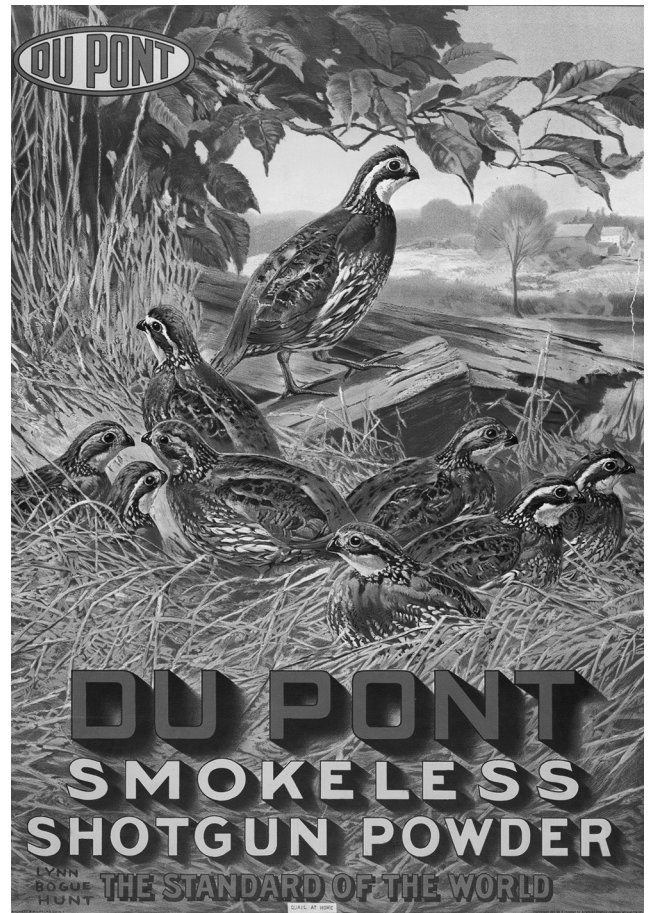
du Pont, Pierre (1870–1954)

Pierre S. du Pont was an American businessman whose work as chairman of both E. I. du Pont de Nemours and Company and General Motors played an important role in the industrial growth of the United States in the first decades of the 20th century.

Pierre S. du Pont was born on January 15, 1870, in Wilmington, Delaware. He was one of 11 children born to Lammot and Mary Belin du Pont. His father, who had moved the family business away from its focus on the production of gunpowder for ammunition and then contributed importantly to the early development of dynamite, died in an explosion, and the 14-year-old Pierre assumed so much of the responsibility for his younger siblings that some of his brothers called him "Dad."

Despite these challenges, du Pont attended William Penn Charter School in Philadelphia and then the Massachusetts Institute of Technology (MIT), from which he graduated in 1890 with a degree in chemistry. Returning to Delaware, he became a chemist in the family business, the DuPont Company, where he codeveloped the company's first commercially usable smokeless gunpowder. In 1899, he left the family business and assumed the presidency of the Johnson Company, a Lorain, Ohio operation that primarily produced rails for trolley and streetcar systems. Working with a cousin, Thomas Coleman, and discovering a skilled assistant in John J. Raskob, the company was a success, but after a short time, it was sold. Then, in 1902, with Coleman and another cousin, Alfred du Pont, Pierre bought and reorganized the family's operations to prevent their purchase by an outside firm. Raskob joined the newly created business as Pierre's assistant. Du Pont served the new company in a succession of roles, including treasurer, executive vice president, and acting president, before finally serving as president from 1915 until 1919. In those roles, he was central in transforming the DuPont Company into what many business historians consider the first modern corporation. His innovations in the technical, financial, and organizational areas were critical to the company's evolution from a family-run business to one that became noteworthy for its professionally managed corporate structure. Du Pont was a driving force behind the decision to divide power, separating the side of the organization that focused on the daily operations of the company from the other branch, which looked at long-range planning and operations.

By the time du Pont assumed the presidency of DuPont in 1915, Raskob, who would go on to head the national Democratic Party under New York governor Al Smith, had become his most trusted aide, and at his urging, du Pont began to purchase large amounts of stock in the newly created General Motors. With DuPont's profits having soared during World War I, the company diversified, adding paint, plastics, and dye to its product line. At the same time, in addition to his own investments, du Pont also had put a lot of the company's money into GM, seeing the company as a prime customer for DuPont paint



This advertisement for DuPont smokeless shotgun powder appeared in 1913, though Pierre du Pont and his cousin Francis Gurney du Pont developed the product in 1892. (Library of Congress)

products and other items. However, under the leadership of mercurial businessman William Durant, in 1920, GM found itself in financial trouble, a condition exacerbated by that year's recession. Major bankers refused to continue their support of GM unless Durant stepped down and du Pont assumed the leadership of the automaker. If only to save the considerable investment of the DuPont Company, Pierre du Pont accepted the presidency of the car company.

While he would only serve until 1923, du Pont's tenure was important. Foremost among his accomplishments was the introduction of cost accounting. He also got rid of a number of money-losing operations, like the small car companies that Durant had regularly acquired, such as Scripps-Booth and Sheridan, but that were, in fact, a drag on GM's bottom line.

In 1923, du Pont moved out of the presidency and assumed the position of chairman of the board, a post he held until 1929, and remained a member of the board until 1944. He was succeeded as president by Alfred P. Sloan, whose long tenure as president was made easier by the changes that du Pont had implemented.

Upon leaving the helm of GM, du Pont continued to sit on a number of corporate boards, holding directorships in companies as wide ranging as the Wilmington Trust Company and the Pennsylvania Railroad, but in general, he turned his focus away from business, becoming increasingly involved in philanthropy and public service. In the immediate aftermath of leaving the GM presidency, he played an active role in the campaign to repeal Prohibition. After that was achieved in 1933, du Pont turned his attention to the world of public education, helping establish the first state board of education in Delaware while also donating millions of dollars to the state's public schools. He made a point of donating funds to replace many of the dilapidated schools that served the state's African American students in the days before *Brown v. Board of Education*. Too, Pierre du Pont was a generous contributor to his alma mater, MIT, while also serving a lengthy tenure on its board of trustees. In addition, du Pont served in a number of public posts, including state tax commissioner. He also transformed the family's estate, Longwood Gardens, putting it under the control of a nonprofit foundation and opening it up to the public.

Pierre S. du Pont married the former Alice Belin in 1915. The couple had no children. He was at the family estate at Longwood Gardens when he died on April 5, 1954, from a ruptured aorta. He is buried in the Du Pont de Nemours Cemetery in Wilmington, Delaware.

William H. Pruden III

See also DuPont Company; *Vol. 2, Sec. 2: General Motors (GM)*

Further Reading

Dupont, Alfred Chandler, and Stephen Salisbury. 1971. *Pierre S. Du Pont and the Making of the Modern Corporation*. New York: Harper & Row.

DuPont Company

Originally a gunpowder company, E. I. du Pont de Nemours and Company (DuPont) was founded in 1802. Since that time, DuPont has expanded its chemical science undertakings to include 13 businesses divided among eight segments: agriculture, electronics and communication, industrial biosciences, nutrition and health, performance chemicals, performance materials, safety and protection, and pharmaceuticals. During the early 2000s, however, the company went through a streamlining process, with the sale of several of its divisions. Then, the company went through a restructuring with a merger in 2017. Due to its research and development efforts, DuPont was responsible for many technological innovations, including the development of nylon, Teflon, and Kevlar.

Éleuthère Irénée du Pont de Nemours (1771–1834), DuPont's founder, learned about the manufacture of gunpowder while working for the French government. After immigrating to the United States in 1797, du Pont built a gunpowder factory along Delaware's Brandywine River. With a reputation for the production of superior gunpowder, the company prospered.

After the founder's death in 1834, his sons, Alfred and Henry, expanded the business to include the manufacture of dynamite and nitroglycerine. With the management help of their cousins, Pierre S. du Pont and Thomas Coleman, DuPont's assets grew to \$24 million. As president, Pierre eliminated competition and increased the company's size by managing the purchase of 54 other companies. By 1905, DuPont controlled 75 percent of the U.S. gunpowder market, its assets were valued at \$64 million, and it had become one of the nation's largest corporations. In 1912, the U.S. government declared that DuPont was a monopoly and ordered a reduction of its size.

However, the company continued to grow during World War I (1914–1918). In addition, in 1914, it expanded into the automobile industry by purchasing 23 percent of all General Motors's stocks (which it held until 1951). After the war, explosives became less profitable. Consequently, DuPont focused research-and-development efforts to developing products for postwar consumer culture, such as

artificial fibers. In the 1920s, DuPont acquired the rights from a French company to produce cellophane in the United States. DuPont marketed it as a moisture-proof packing material for food and other items. During the decade, DuPont also produced rayon and polyester, which were used to make material for clothes.

In 1935, DuPont developers invented nylon, which had many uses, including in undergarments, stockings, tire cords, automobile parts, and brushes. During World War II (1939–1945), DuPont used nylon to produce parachutes, powder bags, and tire cords. After the war, DuPont also developed plastics (notably Lucite, a resin often used as a substitute for glass in paints and enamels) and synthetic rubber. Other notable inventions included Teflon (a nonstick resin used mostly for cookware) and Mylar (a thin, paper-like sheet of plastic with a variety of uses, including in the production of bags and book covers).

Between 1950 and 1970, many DuPont fibers, including Dacron (a type of polyester fiber that is wrinkle resistant and strong), Orlon (a synthetic acrylic fiber used for textiles), Lycra (elastic polyurethane fiber or fabric often used for close-fitting sports clothing), Tyvek (lightweight, high-density polyethylene fiber synthetic paper), Nomex (a heat-resistant metal variant), Qiana (a silky Nylon fiber), Corfam (artificial leather), and Corian (a solid surface material), were critical for the success of the U.S. Apollo Space Project.

During the 1970s, DuPont greatly reduced funding for research in an attempt to cut costs. According to analysts, during these years, DuPont relied too heavily on past inventions and concentrated too exclusively on the fiber market. Unfortunately, the consumer demand for artificial fibers fell during the 1970s, and the company experienced a period of decline. In 1980, however, a rededication to research led to the development of Kevlar, which revitalized the company. Kevlar fibers are light yet five times stronger than steel. Fabrics made of Kevlar are heat and puncture resistant. Many products are made from Kevlar, including heat-resistant gloves and clothing, construction cables, and automobile tire belting. However, the most profitable product to use Kevlar has been the bullet-resistant vest. Within a few years of the

invention of Kevlar, at least half of U.S. police forces wore Kevlar vests.

Since oil is needed to produce synthetic products, DuPont purchased Conoco (the second largest U.S. oil company) for \$7.8 billion. Other acquisitions included Remington Arms (a weapons company), New England Nuclear Corporation (a manufacturer of radioactive chemicals for medical research), and Solid State Dielectrics (a supplier of dielectric materials used in the manufacture of multilayer capacitors). During the next few years, DuPont continued purchasing other companies and sold a wide range of products, including oil, textiles, weapons, pesticides, pharmaceuticals, and electronics. In 1985 alone, DuPont spent over \$1 billion on research and development and employed over 6,000 scientists and engineers.

By the late 1990s, executives believed that DuPont had over extended itself, and they began making plans to sell off parts of the company. In 2001, DuPont sold its pharmaceutical business to Bristol Myers Squibb, and in 2004, DuPont sold its textiles business to Koch Industries. In 2013, the company sold DuPont Performance Coating to Carlyle Group (renamed Axalta Coating Systems). In 2015, DuPont sold its rubber business to Denka Performance Elastomers. Additionally, DuPont whittled down its major product themes to three areas: food, energy, and protection.

In spite of the streamlining, DuPont was still among the largest corporations in the world. From 2009 to 2015, Ellen J. Kullman (1956–), the first woman to be appointed DuPont's chief executive officer, was at the helm of the company, which operated in over 100 countries, employed 70,000 people, and reported yearly sales of about \$35 billion. In 2017, DowDuPont was formed after DuPont merged with Dow Chemical Company. Although DuPont had sometimes faltered, throughout its 200-year history, it had prospered the most from a dedication to the research and development of new innovative products.

Rolando Avila

See also Dow Chemical Company; *Vol. 2, Sec. 2: Petroleum Industry (Pre–World War II)*; *Vol. 3, Sec. 1: Bulletproof Vest/Kevlar*; *Petroleum Industry (Post–World War II)*; *Silent Spring*

Further Reading

- Chandler, Alfred D., and Stephen Salsbury. 1971. *Pierre S. du Pont and the Making of the Modern Corporation*. New York: Harper & Row.
- Taylor, Graham D., and Patricia E. Sudnik. 1984. *DuPont and the International Chemical Industry*. Boston: Twayne.

Duprey, Ana Roqué de (1853–1933)

Scientist and educator Ana Roqué de Duprey, also known as “*Flor de Valle*” (“Flower of the Valley”), is known for her contributions to the founding of the University of Puerto Rico. She is considered an important and pioneering Puerto Rican scientist, feminist, and writer.

She was born on April 18, 1853, in Aguadilla, Puerto Rico, as Ana Roqué Geigel. She learned how to read and write by the age of three. Her mother passed away when she was only four, leaving her to be raised by her father, aunt, and grandmother, who were all educators. By the age of seven, she was sent to a regular school and graduated two years later. At the age of 13, she founded a school in her house and wrote a geography textbook that was later adopted by the Department of Education of Puerto Rico. In 1872, she married Luis Duprey and had five children, three of which lived to be adults. They later moved to the capital of San Juan, where she became the first woman permitted into the Puerto Rican Athenaeum.

In 1884, Roqué accepted a teaching position in Arecibo while also enrolling at the Provincial Institute, where she studied philosophy and science and earned a bachelor’s degree. After the United States invaded Puerto Rico in 1898, Roqué was appointed the director of San Juan’s college for teachers and later taught English in the city of Mayagüez, where she then founded a college. That same year, Roqué founded *La Mujer*, the first women’s-only magazine in Puerto Rico. Roqué also wrote several fiction and non-fiction books, including *Sara*, *La Obrera*, and *Luz y sombra*. In 1903, she was one of the principal founders of the University of Puerto Rico that included her college in Mayagüez.

Despite all of Roqué’s immense contributions to education reform and writing countless magazines as well as fiction and nonfiction books and articles, she is best remembered for her key role in Puerto Rico’s women’s suffragist movement. In 1917, with the help of Ángela Negrón Muñoz and Carlota Matienzo Román, she founded the Feminine League of Puerto Rico. This league was the first group in Puerto Rico with the primary focus on the advancement of women’s rights. In 1921, the group was renamed to the Suffragist Social League, and its focus was now on securing women the right to vote. By 1929, it was given to women who were able to pass literacy tests. Although it was a small step in the advancing of women’s rights, Roqué did not consider it a victory and continued pressuring the Puerto Rican Legislature to recognize the voting rights of all women. It wasn’t until 1935 that all women there could vote, two years after her passing.

Ryan M. Melendez

See also Knight, Margaret; Richards, Ellen Swallow; Vol. 2, Sec. 2: Bryant, Alice; Noether, Amalie Emmy; Vol. 2, Sec. 3: Mead, Margaret; Wu, Chien-Shiung

Further Reading

- Telgen, Diane. 1993. *Notable Hispanic American Women*. Detroit: Cengage Gale.

Duryea, Charles (1861–1938) and Frank (1869–1967)

Charles and Frank Duryea invented the first successful gasoline-powered automobile, which was also the very first of its kind built in the United States. Their first car was successfully tested on the road in September 1893. It had four wheels, metal tires, a single cylinder, and a water-cooled gasoline engine.

In 1891, Charles had completed the design after being inspired by a gasoline engine that he had seen at an Ohio State Fair. With the help of his brother, Frank, he built a car and engine in a Springfield, Massachusetts, loft. Frank and newspaper accounts state that the

car's first test-drive was on September 20, 1893, despite Charles's statement that it happened in 1892. While Charles was in Illinois at that time, Frank did his test drive in Springfield, and he managed to have the vehicle move about 600 feet before its friction-belt transmission failed. However, there was no doubt that it had plenty of potential.

In November 28, 1895, the Duryea brothers entered their second and improved car, which had a two-cylinder engine and pneumatic rubber tires, into what was considered to be the first American automobile race. Eighty-nine entries were filed, but only six were able to participate due to the intensely snowy conditions of that early morning. With the challenge of traveling through a 54-mile round-trip course from Evanston to Chicago, Frank Duryea reached the finish line first after dealing with a series of repairs and malfunctions. At an average speed of about 7.3 miles per hour, Frank had won in just a little over 10 hours, along with a \$2,000 reward. Because the race had been publicized nationally, the car received mass recognition for its practicality, and it was predicted that this would be the end of horse-drawn transportation.

A year after Frank's victory, the brothers founded the Duryea Motor Wagon Company in Springfield, Massachusetts. It was the first American car company that built many cars at a time. In 1896, it manufactured by hand and sold 13 identical cars with the Duryea Motor Wagon brand. Because of this, it was considered the largest automobile factory in United States at that time. Unfortunately, in 1898, the company failed financially, and the brothers decided to part ways after a feud sparked between them.

Charles decided to manufacture three-cylinder automobiles and other vehicles, such as tricycles that were steered using a tiller. On the other hand, Frank continued his success by developing a limousine known as the Stevens-Duryea in the year 1904. His company produced 14,000 units but shut down in the early 1920s.

The car that Frank Duryea ran for 600 feet in Springfield, Massachusetts, resides in the Smithsonian Collection, donated in the year 1920.

Joshua Austria

See also *Vol. 2, Sec. 2: Assembly Line*; Ford, Henry; *Vol. 3, Sec. 1: Electric Car*; *Vol. 3, Sec. 2: Self-Driving Cars*

Further Reading

- Menaugh, John A. 1938. "Five-Mile-An-Hour Victory of 43 Years Ago." *Chicago Sunday Tribune*.
- Parissien, Steven. 2014. *The Life of the Automobile: The Complete History of the Motor Car*. New York: Thomas Dunne Books.
- Schaurchburg, Richard P. 1993. *Carriages without Horses: J. Frank Duryea and the Birth of the American Automobile Industry*. Warrendale, PA: Society of Automotive Engineers.

Earmuffs

Earmuffs are objects that are designed to cover one's ears for warmth or for hearing protection. Earmuffs can be made of many materials, but they generally include a metal or plastic headband that goes over the head. The ends of the headband each have a cup or cushion that covers the ears. The materials for the cups or cushions vary widely and by use. Earmuffs used for warmth use soft, warm materials for the cups, while protective earmuffs generally use plastic or rubber cups.

Chester Greenwood invented earmuffs in 1873, when he was 15 years old. Greenwood lived in Maine and loved to ice-skate, but he found that his ears were often cold. He decided to invent his own type of ear protectors by asking his grandmother to sew flannel pads onto circular loops of wire that he wrapped around his head. Eventually, he would remodel the earmuffs with a better material and design.

The practical earmuff design and structure haven't changed for decades; only the materials have changed, depending on the season and current trends.

Pamela Solis

See also Curling Iron; Jeans; Jockstrap

Further Reading

- McCarthy, Meghan. 2015. *Earmuffs for Everyone!: How Chester Greenwood Became Known as the Inventor of Earmuffs*. New York: Simon & Schuster.

Eastman, George (1854–1932)

Entrepreneur George Eastman founded the Eastman Kodak Company, helping popularize photography for the masses in the late 19th century. His Kodak Black camera was the first camera to use roll film. Eastman also gained fame for founding the Eastman School of Music, a medical school at the University of Rochester, and the Eastman Dental Hospital in London. He also donated portions of his fortune to historically black universities like Tuskegee University and Hampton University.

Born in 1854, Eastman was the third child and only son of George Washington Eastman and Maria Kilbourn Eastman. He grew up on the family farm in Waterville, New York. The family moved to Rochester, a progressive New York town, in 1860. George Washington Eastman died in 1862, and Eastman's sister Katie died in 1870. After this second death, Eastman left school and went to work to support his mother, who took in boarders to earn money, and his remaining sister, Ellen.

In the 1870s, Eastman began to have success with his photography business. He patented the first practical roll film in 1884. Roll film differed from photographic plates in that it was protected from light exposure by a paper backing and because it was rolled into a cartridge. Originally called “sheet film” or “shot-gun cartridge film,” the paper-backed film allowed photographers to load film outside of a darkroom and to make multiple exposures without unwieldy plate changing. Eastman did not invent roll film; Peter Houston did so in 1881. But Eastman's patent allowed for more easily produced and usable film. In 1888, Eastman invented a box camera, the Kodak Black, to use the film. That same year, Eastman joined forces with businessman Henry Strong to found Kodak Company.

On the strength of his wildly popular photographic innovations, Eastman incorporated his company as Eastman Kodak in 1892. The company used a strategy pioneered by razor blade magnate King Gillette. The “razor and blade” strategy held that a company sold affordable products, like razors or cameras, and then sold items that went with them. In Eastman's case, he sold affordable cameras and made a fortune selling roll film.

Eastman never married. He donated over \$100 million to charity, including schools and colleges, in his lifetime. Severe pain stemming from a spinal disorder caused Eastman to kill himself in 1932. Eastman is the only person to have two stars on the Hollywood Walk of Fame, an achievement meant to signal the importance of roll film to the movie industry. He left his house to the University of Rochester, and in 1947, the university chartered the home to become a museum of photography and film. The George Eastman Museum still stands today as a monument to early American film history.

Peg A. Lamphier

See also Eastman Kodak Company; Motion Picture Camera; Roll Film; *Vol. 2, Sec. 2: Safety Razor*

Further Reading

Brayer, Elizabeth. 2015. *George Eastman: A Biography*. Rochester, NY: University of Rochester Press.

Pflueger, Lynda. 2002. *George Eastman: Bringing Photography to the People*. New York: Enslow.

Eastman Kodak Company

Founded in 1888 by George Eastman, Eastman Kodak Company historically manufactured photographic materials, including film, chemicals, and paper. Generally referred to as Kodak, the company introduced products that allowed mainstream Americans to undertake personal photography. Kodak paved the way for recording history; it opened a path for recording vivid personal experiences and it drastically expanded the complexity of photography and its mechanics.

Eastman Kodak Company was founded by George Eastman (1854–1932) and Henry Strong (1838–1919) in 1870. Strong was working in his family's buggy-and-carriage business when he met George Eastman. Eastman was working on dry photography plates. They became partners and named the company Eastman Dry Plate. In 1884, Eastman and Strong concluded their partnership; however, the company had just experienced an expansion that resulted in the creation of “roll film.” This invention allowed Thomas

Edison to develop the motion picture camera. In 1888, Eastman invented a box camera that became the cornerstone of the new company. Kodak was registered as a trademark in 1888.

The company experienced success as it innovated its products throughout the years. In 1895, Kodak introduced a pocket camera. In 1900, Kodak introduced the Brownie camera, named after inventor Frank Brownell. Brownies were the first truly affordable, easy-to-use camera. The Brownie also pioneered the idea of a “snapshot” for Americans, who previously only had pictures taken in formal settings by professional photographers. The Brownie’s design was based on a cardboard box body, simple lenses, and roll film. The first Brownies were sold for \$1. The Brownie 127, which had a Bakelite body and was marketed between 1952 and 1967, was one of the most popular cameras ever sold.

As Eastman Kodak Company expanded, so did its presence in New Jersey and Tennessee. Also, it played a role in World War II, signing contracts with the U.S. military. In 1976, Kodak offered the Kodamatic instant cameras as part of an effort to increase its product selection. In 1986, Kodak introduced the first megapixel sensor for cameras, opening the market to digital photography. Five years later, Kodak offered the first single lens Professional Digital Camera System. In 1994, Kodak manufactured the Apple Quick Take, a digital camera for everyday use. In 2003, Kodak acquired Algotec Systems, an Israeli company, which performed digital management and storage of medical images.

In 2007, Kodak sold the Kodak Health Group for \$2.35 billion, money that it used to pay down debt. In 2009, Kodak announced a job reduction of 4,500 jobs. Sales decreased sharply, leading Kodak to stop producing certain products, such as Kodachrome color film. In 2012, the company filed for Chapter 11 bankruptcy protection, and the aftermath resulted in Kodak’s targeting of commercial customers by offering graphic communications, packaging, and functional printing. As the company had expanded, it had failed to develop a marketing plan to support its business model, and as new technology had arrived, it faced tremendous losses and litigation, and it struggled financially.

Kodak also faced competition from Sony, Canon, and Fujifilm, but mostly by smartphones. Also, its dependency on third-world companies affected it negatively: it could not maintain sufficient control over its suppliers’ mass production.

The company has focused on reconstructing its business around digital printing and making presses and technology to print documents, publications, and product packaging. Kodak is targeting the packing industry as its base for reconstruction by offering smart packaging. Its flexographic solution is a strategy for growth. Industrial packaging is in demand in countries such as China, Brazil, Russia, and India.

Maricela F. Baltazar

See also Camera; Eastman, George; Motion Picture Camera; Roll Film; *Vol. 3, Sec. 2: Digital Photography*; *Vol. 3, Sec. 3: Smartphone and 3G Network*

Further Reading

- Jinks, Beth. 2013. *Kodak Moments Just a Memory as Company Exits Bankruptcy*. New York: Bloomberg Technology.
- Mattioli, D. 2011. “A Struggling Kodak Warns on Prospects.” *The Wall Street Journal Asia*, October.

Edison, Thomas (1847–1931)

The scope and variety of Thomas Edison’s inventions put him in the pantheon of great American innovators alongside Benjamin Franklin and Nikola Tesla. Nicknamed “the wizard of Menlo Park,” Edison can be credited with the invention of the phonograph, the motion picture camera and the first practical lightbulb. Less well known is his invention of a stock ticker, an automated vote counter, and innovations in sound recording and telecommunications. Edison enhanced his ability to innovate with collaboration—particularly at Menlo Park, the nation’s first industrial research laboratory.

Born to Nancy Mathews Elliot and Samuel Ogden Edison Jr. in 1847, Thomas Edison’s family moved from Ohio to Port Huron, Michigan, when he was seven years old. As a boy, he contracted scarlet fever,

complicated by an ear infection that left him hearing impaired. As a result, he struggled in school. Teachers believed he was simpleminded, an impression reinforced by a speech impediment (undoubtedly a complication of his near deafness). Later in his life, he maintained that a train conductor who threw him out of a boxcar when his makeshift chemical laboratory caught fire caused his hearing loss. Edison might not have understood the root of his disability, or perhaps he preferred the more colorful story. His mother removed him from school before his first year of formal schooling was out and educated him at home. Later in his life, he was told that his hearing loss was most likely otitis media, an affliction that could be fixed with surgery. Edison refused the surgery, arguing that hearing might destroy his ability to think.

At 16, Edison took a job as a telegraph operator for the Grand Trunk Railway in Canada. It was on this job that he set up that makeshift laboratory in a boxcar. He lost the job when he nearly caused a train collision. Afterward, he turned his full attention to chemistry, though he continued to work as a “tramp telegrapher” through the Civil War.

In 1866, Edison moved to Louisville, Kentucky, where he worked for the Associated Press and Western Union at night. This left his days open for inventing. In 1869, engineer, explorer, and inventor Franklin Pope took Edison under his wing, allowing the young man to live in the basement of his New Jersey home. The two men founded Pope, Edison and Company Electrical Engineers. Edison invented a one-wire telegraph or stock ticker. Edison also earned his first patent in 1869 for the electrical vote recorder. Edison sold this invention and other telegraphic innovations, most notably the quadruplex telegraph, to Western Union and used the money to establish a research laboratory at Menlo Park, New Jersey, in 1876.

The burgeoning inventor hired a number of assistants and employees, including Swiss clockmaker John Kreusi and Charles Batchelor, an English mechanical engineer. In 1877, Edison invented the phonograph, earning him the nickname “the wizard of Menlo Park” from Americans who thought the phonograph just short of magic. Edison patented the phonograph the next year but did little to promote it until Alexander and Chichester Bell and Charles Tainter

produced a similar device, the gramophone, in the mid-1880s.

In 1878, Edison founded the Edison Light Company to produce a commercially viable lightbulb. In 1879, electrical engineer William Hammer came to work for Edison. The two men collaborated to improve lightbulbs and invented the incandescent lightbulb, solving the problems of earlier types. The next year, Hammer became the chief engineer for the newly formed Edison Lamp Works. Hammer would go on to be chief engineer for the English Edison Light Company, which built an electrical station in London, England.

In 1880, Edison established the Edison Illuminating Company to provide electric light to the masses, putting him in competition with gaslighting companies. The company’s Pearl Street generating station switched on two years later and provided electricity to 59 customers in Manhattan. The rest of the decade found Edison championing his direct current (DC) delivery system, putting himself at odds with George Westinghouse and others’ support of alternating current (AC). Edison maintained that AC was dangerous and would kill people, particularly if used incorrectly. Edison proved correct in this surmise when a number of people were killed by AC in 1888, causing a public outcry against it and the perceived recklessness of companies that used it. Though Edison continued to attack AC, the tide of public opinion gradually changed. The so-called war of the currents fizzled in 1892, when Edison was forced out of his electrical company and J. P. Morgan was installed at the renamed General Electric. Edison suffered another setback when the 1893 World’s Fair decided to electrify with AC. Edison continued to fight for DC, staging a series of AC electrocutions that culminated in the 1903 filmed execution of an elephant named Topsy.

From the “war of the currents” came the now-famous feud between Nikola Tesla and Edison. Tesla, who briefly worked for Edison, first at his machine works and then at one of his power plants, took the AC side of the struggle, arguing that it was more efficient. Tesla also objected to the manner in which Edison monetized and publicized his inventions. Certainly, Edison died a famous millionaire while Tesla spent his life in obscurity.

Edison's Menlo Park laboratory enjoyed so much success that by the time it was a decade old, it had expanded to fill two city blocks. An 1887 newspaper article claimed that Edison's laboratory contained over 8,000 types of chemicals and every type of wire, screw, and needle in existence, as well as more esoteric materials like peacock feathers, cocoon silk, and shark teeth. Edison's facility proved a fertile ground for innovation, giving rise to over 1,000 patents for a wide variety of inventions, including a fluoroscope for taking x-rays and the Kinetoscope, an early motion picture camera.

Indeed, Edison's Kinetoscope spawned an entire industry: motion picture or movie making. Edison demonstrated his moving pictures in the mid-1890s in New York and Europe. In 1894, the inventor established Edison Studios, first as Edison's Black Maria in New Jersey. In 1901, the studio moved to Manhattan and six years later to the Bronx. Edison delegated control of the company to others and played no part in early movie making. The studio would make over 1,200 films, 54 of which were feature length. Many of the films are considered classics of film history, including *The Kiss* (1896), which featured the first on-screen love scene, and *The Great Train Robbery* (1903), the first Western.

During his long career, Edison also investigated mining and cement production with his Edison Ore Milling Company and battery technology with the Edison Storage Battery Company. Edison also collaborated with Harvey Firestone and Henry Ford to establish an American supply of rubber.

Edison married twice. In 1871, he married Mary Stilwell, a 16-year-old employee. The couple lived in Menlo Park and had three children: Marion, Thomas Jr., and William. Mary Edison died in 1884 from complications stemming from a brain tumor and the morphine she took for pain. Less than two years later, Edison married Mina Miller, daughter of inventor Lewis Miller. They moved to Llewellyn Park, also in New Jersey, though the couple wintered in Fort Meyers, Florida, at a home they called Seminole Lodge. The couple had three children: Madeleine, Charles, and Theodore. Edison left the childrearing to his wives, preferring time spent in his laboratories to time spent with his family. William, Charles, and Theodore all became inventors and research engineers.

In his later years, Edison spent more time in Fort Meyers, Florida. Henry Ford, who began his career working for Edison, lived in the house next to Seminole Lodge, and the two men belonged to the same community service organization, the Civitan Club. In 1930, not long before he died, Edison opened the Lackawanna Railroad, an electrical (DC) railroad in New Jersey, and drove the first mile of the train's inaugural journey.

In 1931, Thomas Edison died from diabetes complications at his home in New Jersey and was buried on the grounds. Since his death, he has been widely honored as one of America's greatest inventors. Lakes, colleges, ships, asteroids, and towns have been named after him. Companies still bear his name, including Southern California Edison and the Edison Portland Cement Company. It is difficult to overstate Thomas Edison's influence on American society.

Peg A. Lamphier

See also Bell, Alexander Graham; Electric Lightbulb; General Electric; Motion Picture Camera; Phonograph; Tesla, Nikola; *Vol. 1, Sec. 1*: Franklin, Benjamin; *Vol. 2, Sec. 2*: Ford, Henry

Further Reading

- Cawthorne, Nigel. 2016. *Tesla vs. Edison: The Life-Long Feud that Electrified the World*. New York: Chartwell Books.
- Newton, James. 1989. *Uncommon Friends: Life with Thomas Edison, Henry Ford, Harvey Firestone and Charles Lindbergh*. New York: Mariner Books.
- Stross, Randall. 2007. *The Wizard of Menlo Park: How Thomas Alva Edison Invented the Modern World*. New York: Crown.

Electric Iron

American inventor Henry W. Seely developed and patented the electrically heated iron in 1881. His signature can be found on over 100 patents, including some that belong to Thomas Edison's inventions.

Seely initially came up with his design of an electric iron in 1881 and applied for a patent for it the following year. His invention offered an alternative to the



This vintage illustration, ca. 1920, of an early electric iron illustrates its sleek, clean design. Inventor Henry Seely kept only one third of the rights to his patent, assigning the other two thirds to Samuel Insull and Richard N. Dyer, Thomas Edison's patent attorney. (GraphicaArtis/Getty Images)

heavy and difficult-to-use charcoal-burning and gas-heating irons of the 19th century. The electrically heated iron allowed for a much cleaner and faster workflow, since ash was easily spilled from the charcoal-burning iron to the clothes, and other irons had to be placed on a stove for reheating.

Together with his partner, Richard N. Dyer, Seely worked on a different design in 1883 because they had doubts about having the iron continuously plugged into an electrical circuit. They invented a cordless iron that could be reheated on an electrically powered stand.

During the 20th century, steam was the primary means of heating irons; however, Seely's concept of the electric iron proved to be a practical invention that we still use today.

Patrick Ketterer

See also Curling Iron; *Vol. 2, Sec. 2: Blender; Pop-Up Toaster*

Further Reading

Jonnes, Jill. 2003. *Empires of Light: Edison, Tesla, Westinghouse, and the Race to Electrify the World*. New York: Random House.

Electric Lightbulb

Thomas Edison (1847–1931) has been credited for inventing the first successful incandescent lightbulb in 1879. The lightbulb changed the world in many ways. It replaced more primitive ways of lighting, and it transformed home life, entertainment, and work. In more recent years, critics, legislators, and researchers

have sought to make the electric lightbulb more energy efficient.

Before the invention of the lightbulb, towns and cities were lighted by gas lamps, and people in the countryside lit their homes with oil lamps and candles. Reading or doing any kind of intricate work with these types of light sources was difficult, because the light they produced was neither steady nor bright enough. Early inventors hoped that running an electric current through some sort of fiber would create a glow of light. Unfortunately, these experiments failed, because the fiber melted after a few seconds or minutes.

Edison, an American inventor and businessman, conducted research on more than 3,000 different fibers. He finally settled on a thin filament of carbon made by burning a thread of chemically treated cotton. With the help of his lab team, Edison realized that the filament would glow much longer if he placed it inside a glass globe from which all the air was removed. On October 21, 1879, after many attempts, Edison's lightbulb glowed for 13 hours before the glass cracked. Edison was then able to extend the life of the lightbulb dramatically by making the glass more resistant to heat.

Edison advertised his new invention by lighting Menlo Park, New Jersey, at night. The spectacle caused a great sensation. However, as a consumer good, the lightbulb was worthless without a supply of electricity. With the financial support of J. P. Morgan, Edison formed the Edison Electric Light Company, which began supplying homes in Manhattan in New York City with electricity in 1882. Edison's use of direct current (DC) required that he build generators on every city block. Nikola Tesla, one of Edison's former employees, invented a motor in the 1880s that produced alternating current (AC), which could distribute electricity more cheaply and over longer distances than DC. Although Edison dismissed AC as unsafe, it would eventually replace DC.

For many years, only the wealthy in large cities benefited from the use of electric lightbulbs. It took many years for the use of electricity in most homes to catch on, because the wiring of existing homes was expensive. It was not until the 1920s and after many new homes were built with electric wiring that many new consumer goods for the home became popular, including radios, refrigerators, vacuum cleaners,

electric irons, bread toasters, washing machines, and dishwashers. Many of the new appliances made housework easier.

Transportation was also changed as headlights were mounted on automobiles and trains, making night travel safer. By using a lightbulb to project a strip of photographs on a big screen, Edison gave birth to the motion picture industry, which revolutionized entertainment. Before the use of the lightbulb and electricity, U.S. industry used lamps for lighting and steam to power factory machines. Its transition to the use of the lightbulb extended working hours, and electricity made factory machines more productive.

In more recent years, energy-conscious critics of the incandescent lightbulb charged that it was wasteful. In response, the U.S. government passed a law that required bulbs as bright as earlier 40-watt bulbs to draw only 10.5 watts and those with the brightness of formerly 60-watt bulbs just 11 watts. By 2014, all incandescent lightbulbs were phased out because they could not meet the government standard, though fluorescent lightbulbs continued in wide use. In 2016, a team of researchers from the Massachusetts Institute of Technology (MIT) claimed that it had developed a lightbulb that was much more energy efficient than compact fluorescent bulbs (CFLs) and light-emitting diode (LED) bulbs.

Rolando Avila

See also Edison, Thomas; Electrification, Urban; Tesla, Nikola; *Vol. 2, Sec. 2: Washing Machine, Electric*

Further Reading

- Freeberg, Ernest. 2013. *The Age of Edison: Electric Light and the Invention of Modern America*. New York: Penguin Press.
- Friedel, Robert D., Paul Israel, and Bernard S. Finn. 1986. *Edison's Electric Light: Biography of an Invention*. New Brunswick, NJ: Rutgers University Press.

Electricity, War of the Currents

The “war of the currents” was the name given to a series of disputes that occurred during the last two decades of the 19th century concerning how electrical

power would be distributed on a national basis within the United States. The disagreement erupted into a feud between Thomas Alva Edison (1847–1931) and Nikola Tesla (1856–1943), the inventors of the competing electrical distribution systems.

Edison, after developing a commercially successful electrical lightbulb in 1879, began working on a way to distribute electrical power to consumers as a replacement for the existing gaslighting system. In December 1880, he founded the Edison Illuminating Company, and by late 1882, he had a generating station in New York City that provided electrical power to customers.

The system of electrical power distribution (transmission) that Edison developed was a direct current (DC) system. In a DC circuit, electrical current flows in only one direction and has a constant polarity. Edison's DC system worked well, and by the mid-1880s it had become the national standard. Edison earned many royalties from his direct current patents, which included an electrical utility meter that measured how much power a customer used.

One of the main technical drawbacks with the Edison DC system was that the voltage could not be easily changed for use with different electrical loads. This meant that most practical electrical applications in use at the time, which included lights and motors, needed their own separate power supply lines to provide the correct voltage.

A competing electrical transmission system was alternating current (AC), which had been developed in Europe during the 1880s by a number of electrical pioneers. The earliest AC systems in the United States used extremely high voltages to distribute power, and because of this, they were prone to sparking. A number of deaths were caused by the high-voltage lines, and there was widespread belief that the power companies were deliberately putting the public at risk.

Tesla knew that AC was more efficient at transmitting electrical power over longer distances and believed that the inherent problems with the distribution system could be mediated. However, Edison argued in favor of DC power distribution, citing the dangerous voltages used with AC power transmission systems. But Edison also had a monetary stake in the

outcome of DC versus AC, and he was not keen on the prospect of losing market share for electrical distribution.

In 1886, William Stanley Jr. (1858–1916) successfully provided electricity to a town with alternating current. The “Great Barrington Electrification” took place on March 20 in Great Barrington, Massachusetts, where Stanley had set up a complete AC power system that included a 500-volt generator and his new step-up and step-down transformers. Stanley demonstrated that AC could be used safely and that it could provide electricity to more customers than a DC system of the same size.

In 1887, Tesla filed seven patents for his complete polyphase AC system, which included transmission lines and generators and transformers. George Westinghouse (1846–1914) believed that Tesla's system was capable of producing long-distance power transmission and purchased Tesla's patents, offering Tesla a share of stock in his company.

By now, Edison realized that his DC power system was up against stiff competition. His reaction was to show how dangerous AC power could be. A number of people entered the fray on both sides of the AC/DC current war, including electrical engineer Harold Pitney Brown (1857–1944). Brown unsuccessfully lobbied to reduce the voltage of existing AC power transmission lines after several people in New York were killed by electrical shorts and arc lightning from AC power lines.

However, Brown had no qualms about animal welfare. Instead, he publicly electrocuted several dogs to show how dangerous AC was. When he heard that New York had decided to use death by electrocution instead of hanging for death sentences, Brown addressed the committee tasked with the chore of deciding on whether to use AC or DC and electrocuted a horse and several cows using 750-volt AC power. The committee was convinced, but it recommended using a higher voltage for human executions.

On August 6, 1890, convicted murderer William Kemmler (1860–1890) became the first person to be electrocuted to death. Brown had surreptitiously purchased the Westinghouse AC generator that was used in the botched execution, which lasted for nearly eight

minutes and produced such a horrible scene that electrocution became known as “Westinghousing.”

Westinghouse underbid rival company General Electric and got the contract to electrify the 1893 Chicago World’s Columbian Exposition, which was the first fair to be lit by electricity. Westinghouse was able to keep his price low because an AC power distribution system is more efficient than a DC system and requires less wiring, making it more cost-effective. The “City of Light” was illuminated by more than 100,000 incandescent lightbulbs powered by a dozen AC generators, and the Electricity Building housed several AC power exhibits.

The “war of the currents” continued into the 20th century. On January 4, 1903, Topsy the elephant was electrocuted at the Luna Park Zoo on Coney Island, New York. Topsy was shot through with 6,600 volts of AC, which instantly killed her. The gruesome spectacle was documented and released as an Edison film, *Electrocuting an Elephant*.

Karen S. Garvin

See also AC Generator and Transformer; Edison, Thomas; Electrification, Urban; Tesla, Nikola; World’s Fairs

Further Reading

- Carlson, W. Bernard. 2013. *Tesla: Inventor of the Electrical Age*. Princeton, NJ: Princeton University Press.
- Cooper, Christopher. 2015. *The Truth about Tesla: The Myth of the Lone Genius in the History of Innovation*. New York: Quarto.
- Daly, Michael. 2013. *Topsy: The Startling Story of the Crooked-Tailed Elephant, P. T. Barnum, and the American Wizard, Thomas Edison*. New York: Atlantic Monthly Press.
- Jonnes, Jill. 2004. *Empires of Light: Edison, Tesla, Westinghouse, and the Race to Electrify the World*. New York: Random House.
- Klein, Maury. 2008. *The Power Makers: Steam, Electricity, and the Men Who Invented Modern America*. New York: Bloomsbury Press.
- Stross, Randall. 2007. *The Wizard of Menlo Park: How Thomas Alva Edison Invented the Modern World*. New York: Three Rivers Press.

Electrification, Urban

Electricity is commonly transported to cities to power consumer appliances. Most of these appliances serve to provide light, automate processes, send information, or entertain. Power transmission is the transportation of electricity by bulk to be distributed to individual customers. Electricity is produced in power plants and transported through power lines in high voltage to prevent power loss. The voltage is then lowered into cities for consumer usage. Most cities have energy transmitted through alternating current; however, there are different methods to transfer electricity, including high-voltage direct current, which is used to send power over long distances. This electricity is sold by usage amount or time and measured in megawatts.

Most power is stored in power plants through various means. The most common method of storage is dammed hydroelectricity, which stores electrical energy as potential energy by pumping water against gravity. The potential energy created is then released, to be converted back into electricity. This method is used to store energy when it is not needed and release energy when there is a higher demand. This is done to provide a consistent amount of energy to cities. In cities, electricity is stored in batteries. Batteries use the energy transmitted through power lines and convert it to potential energy that is stored in containers. Most batteries store potential energy by polarizing chemical structures within their containers and then release a direct current through the appliances connected to them. Batteries are used around cities to transport and use energy without the need to be connected to power lines.

In the early days of energy transmission, energy was distributed in different voltages. This was because different appliances in cities needed different voltages. Because of this, energy generators had to be close to provide energy. There were specific lines for light, appliances, and rail transportation. Most of these early technologies of electricity were developed and used in Paris, London, Germany, and Rome—for example, the electromechanical generator made by Ernst von Siemens in the 1860s. One of the first companies to supply electricity as a utility was the California Electric Company in San Francisco in 1879. The utility

supplied power for light. During this time, the arc lamp was rising in popularity within industry, prompting San Francisco City Hall to be lit up in 1880.

In 1882, the Edison Illuminating Company began operation of the Pearl Street Station in Manhattan, New York City, the nation's first central electrical power plant. The Pearl Street Station used the new system of a centralized, direct current power station and served several businesses through an underground line. Likewise, this was the first introduction to the United States of an organized source of power, measurements for power usage, and power switches. In 1886, William Stanley Jr. was hired by Westinghouse Electric Company and perfected the closed core transformer. At this time, Westinghouse also purchased rights to the patents by Nikola Tesla of alternating current, which was widely used in Europe. Within that same year, the first American alternating current system was created in Great Barrington, Massachusetts. This system had a step-up and step-down transformer, which shaped the way we now transport power. The system continued to be refined, and two years later the first alternating current power station for long-distance transmission went online in Portland, Oregon.

In 1890, Westinghouse had 300 alternating current plants. At this time, there were 1,500 direct current stations by Edison. There was, therefore, tension between power companies as the United States looked for a more universal source of electricity. In the end, it chose alternating current as its standard, putting in place the structure we use today. Alternating current proved more advantageous for induction motors, which were used to industrialize production. Likewise, the usage of step-up and step-down transformers supplied a universal system, while direct current, though less efficient, continues to power some devices.

In 1890, Westinghouse created the first hydro-power station. It used alternators that produced power of 3.5 megawatts, reducing the cost of energy production. By 1902, this format provided electricity for a fifth of the United States. Mine mouth plants, or plants placed close to coal mines, also began creating electrical energy, particularly in the coal rich regions of the United States.

From this time on, technology further improved throughout the United States. More hydro plants

were created to distribute enough power to cities. Previously, electricity had been used by industry and to provide light in public places in the United States approaching the 20th century. After World War I and World War II, the creation of government-run power plants and postwar prosperity made electricity widely available to the consumer. By the 1930s, electricity was distributed all over the United States.

By the 1920s, the creation of home appliances like the freezer, the television, radio, and the washing machine called for further distribution of electricity. This was especially true for light sources like the incandescent light and air-conditioning for businesses and homes. With the increased use of electrical appliances, circuit breakers and safer transformers were created to prevent fires within cities. This raised American living standards. Industry likewise was revolutionized by automating labor like rock cutting, loading, and treadmill transportation, making mass production easier.

In the 1950s, the creation of computing and the consumer use of more electric appliances prompted more demand for electricity. This prompted electrical companies to create programs that made it cheaper for consumers to buy electricity during off-peak times while charging more during active times. By this time, the increased number of coal and gas plants created problems with pollution.

To help meet energy demands, nuclear technology was harnessed to produce power. The Atomic Energy Act of 1954 encouraged research into nuclear energy and nuclear power plants. However, the Price-Anderson Nuclear Industries Indemnity Act in 1957 made it hard for nuclear power plants to be built after there were several meltdowns. And in the 1970s, several programs arose to encourage nuclear power plants, but after protests were held against them, they failed. The United States had 99 nuclear reactors in 2016.

As of 2015, the total energy use in the United States was up to 3.86 trillion kilowatt-hours. Of them, 38 percent accounted for residential use while 36 percent was for commercial and 26 percent for industrial uses. Air cooling continues to be one of the largest users of electricity in the residential sector, combined

with refrigeration, lighting, water heating, and television. Lighting is one of the largest factors in the commercial sector, while machine drives are the largest users of electricity in industry.

Because of the continuous need for power and electricity, cities have been exhausting sources of electricity and causing pollution. This has created an energy crisis. The increased use of fossil fuels has released carbon dioxide into the environment, causing climate change. Likewise, the continued use of fossil fuels has created a scarcity, increasing energy prices. We have been looking for alternative methods of energy that give us the energy we need but do not undermine the climate.

Alternative sources of electricity used in the United States have included solar energy, hydroelectricity, wind energy, geothermal energy, and tidal energy. The country has improved efficiency to reduce the waste of energy, and it is trying to transition from fossil fuels to more sustainable systems. The United States has also been encouraging the use of more energy-efficient products and subsidizing some, such as home solar panels or electric vehicles, to reduce its emissions from the use of fossil fuels.

George P. Quan

See also Edison, Thomas; Electricity, War of the Currents; Tesla, Nikola; *Vol. 2, Sec. 3*: Tennessee Valley Authority Electricity Project (TVA); *Vol. 3, Sec. 2*: Solar Energy

Further Reading

- Guarnieri, Massimo. 2013a. "The Beginning of Electric Energy Transmission: Part One." *IEEE Industrial Electronics Magazine* 7, no. 1: 50–52.
- Guarnieri, Massimo. 2013b. "The Beginning of Electric Energy Transmission: Part Two." *IEEE Industrial Electronics Magazine* 7, no. 2: 52–59.
- LeClair, T. G. 1944. "Electrical Engineering in the Postwar World: V. The Electric-Power Industry after the War." *Electrical Engineering* 63, no. 9: 338–41.
- Nebeker, Frederik. 2009. *Postwar Recovery and the Great Depression: Electrical Technologies in Industry and Commerce*. New York: Wiley-IEEE Press.

Escalator

Escalators, while common today, were once considered exotic, reaching the status of tourist attraction in some mid-20th-century towns. In many parts of the country, people recall their families traveling for miles to visit department stores that had escalators installed. One such business, the seven-story Gus Blass company in downtown Little Rock, was the first in Arkansas to install an escalator, and it drew crowds from around the state. In 1950, *Chain Store* magazine featured it in a Westinghouse ad that claimed, "Each of the 'Limited Budget' Westinghouse Stairways is capable of carrying 5,000 passengers at 90 feet per minute." As if at a theme park, people stood in line to ride them.

The escalator concept is simple: a moving staircase carries people up or down using tracks and a conveyor belt while keeping each step level for the passenger to stand on. The first escalator type of apparatus appeared two years after the first passenger elevator. Patent number 25,076 was granted in 1859 to Nathan Ames (1826–1865) for an invention he called "Revolving Stairs." The continuous revolving belt on which the escalator steps were mounted allowed the machine to carry passengers up or down. Ames envisioned the future in his patent application: "... buildings may be constructed much higher than heretofore, as the previous objections to such structures will be obviated."

Ames's steam-driven Revolving Stairs design is generally acknowledged as the world's first escalator, though he never produced a working model. His prototype drawings had design flaws, including the necessity for passengers to jump sideways to get off. Soon, his vision was fine-tuned by several inventors who received patents for "moving stairways," including Jesse Reno and George Wheeler in 1892. Ironically, given the escalator's attraction for middle America in the next century, Jesse Reno created a new novelty ride for Coney Island based on his patented design, a moving stairway that elevated passengers on a conveyor belt at a 25-degree angle.

The escalator as we know it was patented in 1898, having been modified by Charles Seeberger. Seeberger worked with the Otis Elevator Company to produce

the first commercial escalator in 1899. At the 1900 Exposition Universelle in Paris, France, the Seeberger-Otis wooden escalator won first prize. After Otis purchased patent rights from both Seeberger and Reno, Otis combined, improved, and marketed various escalator designs.

In addition to producing today's recognizable escalator, Seeberger also coined the current terminology. To coincide with his display at the 1900 Exposition Universelle, Seeberger wrote that he took the word "*scala*" from the Latin, as in to scale a hill, adding a modern-sounding prefix and suffix. He intended the word to be pronounced "es-CAL-a-tor." By 1950, however, the Otis company's exclusive use of the word "escalator" ended when a court decided that it had entered public domain as a generic term and removed trademark protections.

Whatever their nomenclature, escalators typically come in several configuration options: crisscross ("stacked" escalators traveling in one direction per side, often used in department stores or shopping centers to minimize space requirements), parallel (up-and-down escalators, either side by side or separated by a distance, seen often in subway stations), and multiple parallel (two or more escalators together that travel in one direction next to one or two escalators in the same bank that travel in the other direction). Visually attractive spiral escalators are also being utilized in contemporary designs.

Modern refinements include the option of changing the up or down direction of the escalators depending on traffic patterns to accommodate such events as rush hour, stadium crowds entering or leaving an arena, etc. Escalators are also required to have moving handrails that keep pace with the steps as a safety measure so riders can steady themselves. Escalators are often located near elevators that wheelchair-bound or disabled people can use.

Escalators have the ability to move large numbers of people in the same physical space as a staircase. Except during very heavy traffic, there is no waiting time to board. They can be used to guide people toward main exits or special exhibits, and they can be weatherproofed for outdoor use. Escalators have one additional advantage over most modern technology. When they break down, the steps remain horizontal, allowing them to be used as conventional staircases while

most other conveyances become useless in a breakdown.

Nancy Hendricks

See also *Vol. 1, Sec. 3: Elevator Safety Brake*

Further Reading

Goodwin, Jason. 2001. *Otis: Giving Rise to the Modern City*. Chicago: Ivan Dee.

Strakosch, George R. 1983. *Vertical Transportation: Elevators and Escalators*. Hoboken, NJ: Wiley.

Strakosch, George R., and Robert S. Caporale, eds. 2010. *The Vertical Transportation Handbook*. Hoboken, NJ: Wiley.

Ferris Wheel

The Ferris wheel was the main attraction at the 1893 Chicago World's Columbian Exposition. The 264-foot tall wheel could be seen towering above other fair-ground attractions even before visitors entered the park.

In 1890, the U.S. Congress decided that Chicago would host a fair in honor of the 400th anniversary of Columbus's discovery of the New World. Illinois chartered a corporation known as the World's Columbian Exposition to design and build the fair, and in 1891, the corporation appointed architect Daniel H. Burnham (1846–1912) to head the design committee.

At a meeting of architects and civil engineers, Burnham goaded his audience into designing a suitably impressive structure to provide a focal point for the fair that would outclass the Eiffel Tower, which had debuted at the 1889 Paris Exposition.

One audience member was George Washington Gale Ferris Jr. (1859–1896), an 1881 graduate of Rensselaer Polytechnic Institute. Ferris had worked for a New York firm for five years before founding his own companies: G. W. G. Ferris Engineering Company in 1886 and Ferris and Kaufman Engineers in 1890.

Ferris designed a revolving steel tension wheel that would be sturdy enough to endure hurricane-strength winds. The 250-foot diameter wheel was comprised of two separate wheels held together by struts and supported by a 45-foot forged steel axle that weighed nearly 90,000 pounds.

The first design that Ferris submitted to the fair committee was approved, but doubts about the wheel

made them change their minds. Undaunted, Ferris revised his drawings and resubmitted them in November 1892, along with \$600,000 that he had raised to fund the project. He won the concession, and the wheel was slated to be built along Central Avenue, on the fair's midway.

Time was short: Ferris had only four months to construct his wheel. The winter was exceptionally harsh, and steam had to be pumped into the ground to thaw it for construction. Piles were driven 32 feet into bedrock and overlain with steel beams, which in turn supported massive concrete piers that would hold the giant wheel.

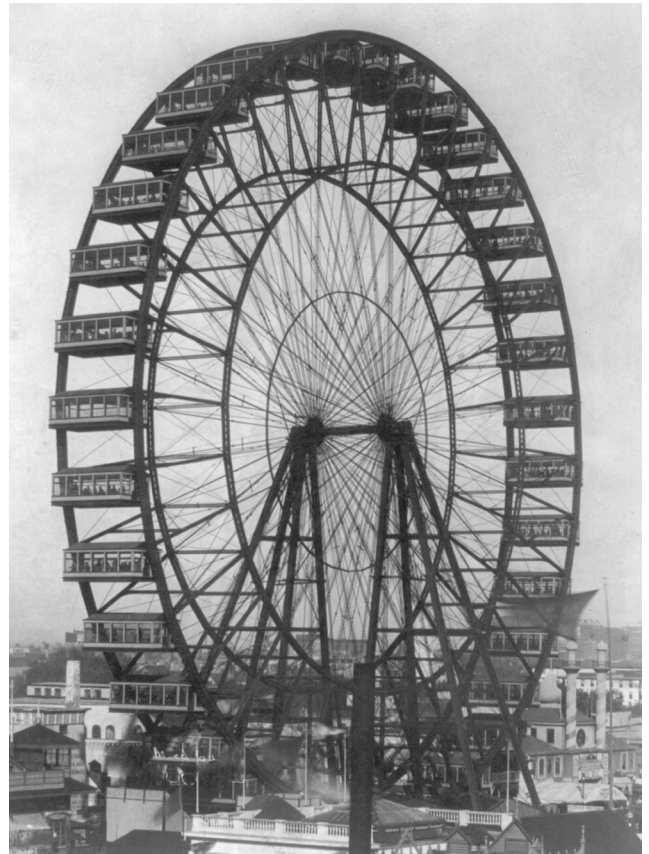
The completed axle was delivered in mid-March and assembly began on the wheel. A 1,000-horsepower steam engine was used to power the wheel while a second engine was kept as a backup. The ride was also equipped with a Westinghouse air brake.

When the fair opened on May 1, 1893, the ride was still under construction. On June 9, it was successfully tested without any of the 36 wooden cars attached to the frame. The next day, workers began the final assembly process of hanging the 24-foot-long cars and completing the loading platforms. More than 3,000 Edison lights adorned the wheel.

On June 21, the Ferris wheel was opened to the public, and it quickly became one of the main attractions of the fair. People were amazed that something that seemed so fragile could support itself, let alone carry more than 2,000 passengers aloft at a time. The 50-cent fare allowed rides of two revolutions of the wheel, allowing passengers time to admire the midway or to turn their gazes toward the White City, so named for its neoclassical exposition buildings covered with stucco.

When the fair closed on November 1, more than 1 million people had ridden the wheel. It was dismantled in April 1894 and reassembled in Lincoln Park, where it reopened in October 1895. Ferris had partnered with streetcar magnate Charles Tyson Yerkes (1837–1905) to build a restaurant, theater, and rides. But the ride was not a financial success, and by 1896, Ferris was bankrupt. He died on November 22, 1896, of typhoid fever.

The wheel continued in operation at Lincoln Park until 1903, when it was dismantled and taken to St. Louis for the 1904 World's Fair. After another



A ferris wheel debuts at the 1893 Chicago World's Columbian Exposition. Invented by George W. Ferris, the amusement park ride proved popular. (Library of Congress)

disappointing financial performance, Ferris's wheel was dynamited on May 11, 1906.

Karen S. Garvin

See also Edison, Thomas; Electric Lightbulb; Electricity, War of the Currents; World's Fairs; Yerkes Observatory

Further Reading

- Anderson, Norman. 1992. *Ferris Wheels: An Illustrated History*. Bowling Green, OH: Bowling Green State University Popular Press.
- Bolotin, Norman, and Christine Laing. 2002. *The World's Columbian Exposition: The Chicago World's Fair of 1893*. Champaign, IL: University of Chicago Press.
- Weingardt, Richard. 2009. *Circles in the Sky: The Life and Times of George Ferris*. Reston, VA: American Society of Civil Engineers.

Primary Document: Telegrams between Luther Rice and George Ferris Following the Successful Test of the Ferris Wheel (1893)

Planners of the Chicago World's Fair of 1893 wanted a structure that would rival the wonder that was the Eiffel Tower, built for the 1889 World's Fair in Paris. George Ferris proposed a revolving wheel with a 250-foot diameter that would carry cars of people in circles. Nothing like it had ever been built. Ferris had designed the wheel but was not in Chicago as it reached completion. The following are telegrams between Luther Rice and George Ferris upon a successful test of Ferris's wheel.

Chicago ILL June 9, 1893 To: George W. G. Ferris The last coupling and final adjustment was made and steam turned on at six o'clock this evening—one complete revolution of the big wheel was made—everything working satisfactorily—twenty minutes time was taken for the revolution—I congratulate you upon it—complete success—Midway [Plaisance] is wildly enthusiastic. L.V. [Rice]

Pittsburgh, PA June 10, 1893 To: L.V. Rice [sic] Ferris wheel Your telegram stating that first revolution of wheel had been made last night at six o'clock and that same was successful in every way has caused great joy in this entire camp. I wish to congratulate you in all respects in this matter and ask that you rush the putting in of cars

[June 10, 1893, side 2] working day and night-if you can't put the cars in at night habbitt [i.e. hobble] the car bearings at night so as to keep ahead. Please take [sic] the Changes in the posts at once and rush same through with all possible speed-will be in Chicago the first of the week. Geo W. G. Ferris

Source: Telegram concerning the Ferris wheel at the 1893 World's Fair. Chicago Historical Society, George Washington Gale Ferris papers.

Folding Cabinet Bed

The folding cabinet bed is a bed that, when not in use, can be folded into a desk that also has compartments for storage. The folding cabinet bed was designed and created by Sarah Elizabeth Goode.

Sarah E. Goode was an inventor and entrepreneur who was born in Toledo, Ohio, in 1855. She was the second of seven children. Her father, Oliver Jacobs, was a carpenter, and after the Civil War in the United States, she and her family received their freedom and moved to Chicago, Illinois. She met and married Archibald Goode and had six children with him. Archibald himself was a stair builder and upholsterer, and the couple opened a furniture store together. Goode developed and patented the folding cabinet bed in 1885. Her idea of the folding cabinet bed came out of a necessity of the times. Most of her customers were working class and lived in small spaces without much room for furniture. Her invention was a precursor to the Murphy bed, which was

patented in 1900. She was also one of the first African American women in the United States to receive a patent. Goode died in 1905 in Chicago, Illinois.

Goode's bed was designed to fold into a desk. The bed is made with three sections. The center section has a rectangular frame, and its length corresponds to the length of the bed. The left and right sections are hinged to the center section on opposite sides. The hinged section is constructed so that when the bed is folded, it forms an upright box that holds the mattress inside. The sections can also be constructed to form a desk-like structure so it can be used when the bed is folded. When the bed is unfolded, one of the hinged side sections forms the headboard; it can also act as the table portion of the desk. Additionally, there are braces on each side of the bed to hold it in place while unfolded. The braces also are the sides of the desk. The folding bed also has drawers that can be used when the bed is either folded or unfolded. The part of the bed where the mattress lies

is supported just like that of any nonfolding bed. Usually a spring mattress is used for the folding beds, but any type of mattress can be used.

Hannah Reutershan

See also *Vol. 1, Sec. 1*: Glover, Elizabeth; *Vol. 1, Sec. 2*: Blackwell, Elizabeth; Greene, Catharine Littlefield; *Vol. 1, Sec. 3*: Crumpler, Rebecca; Walker, Mary

Further Reading

Miller, Jeff. 1999. *Beds: Outstanding Projects from One of America's Best Craftsmen (Step-By-Step Furniture)*. Newtown, CT: Taunton Press.

Van Dulken, Stephan. 2004. *American Inventions a History of Curious, Extraordinary, & Just Plain Useful Patents*. New York: New York University Press.

Primary Document: Patent for Folding Cabinet Bed (1885)

In 1885, Sarah Goode became the first black woman to obtain a patent from the U.S. government. Her cabinet bed is the forerunner of the modern Murphy bed and is still considered an ingenious space-saving piece of furniture.

SPECIFICATION forming part of Letters Patent No. 322,177, dated July 14, 1885. Application filed November 12, 1883. (No model.)

To all whom it may concern.

Be it known that I, SARAH E. Goode, a citizen of the United States, residing at Chicago, in the county of Cook and State of Illinois, have invented a certain new and useful Improvement in Cabinet-Beds, of which the following is a full, clear, concise, and exact description, reference being had to the accompanying drawings, forming a part of this specification.

This invention relates to that class of sectional bedsteads adapted to be folded together when not in use, so as to occupy less space, and made generally to resemble some article of furniture when so folded.

The objects of this invention are, first, to provide a folding bed of novel construction, adapted, when folded together, to form a desk suitable for office or general use; second, to provide for counterbalancing the weight of the folding sections of the bed, so that they may be easily raised or lowered in folding or unfolding the bed; third, to provide for holding the hinged or folding sections securely in place when the bed is unfolded, and, fourth, to provide an automatic auxiliary support for the bedding at the middle when the bed is unfolded.

My invention consists in the arrangements and combinations of parts hereinafter described, and pointed out in the claims.

In the accompanying drawings, Figure 1 is a perspective View of my improved folding bed folded together so as to form a desk, which is shown open. Fig. 2 is a partial vertical sectional view of the same, showing the desk closed. Fig. 3 is a longitudinal sectional view of the bed unfolded. Fig. 4 is a sectional view of the same on line m x in Fig. 3. Figs. 5 and 6 are views of portions of the bed in detail, referred to hereinafter.

Like parts are indicated by similar letters of reference throughout the several views.

The main frame of the bed I make in three sections, A B C. The center or stationary section, A, consists of a stout rectangular frame, of a length corresponding to the width of the bed, and of sufficient width to form, in connection with the folding sections B and C, when folded together thereon, a receptacle large enough to contain the necessary bedding. The folding sections B C are hinged to the stationary section A on opposite sides thereof, so that when unfolded the stationary section A becomes the middle portion of the bed, while the folding sections B C form the respective end portions thereof, the width of the stationary section A being thus included in the length of the bed when unfolded. By this well-known construction a full-length bed 60 may be obtained which will occupy but little vertical space when folded up. The hinged or folding sections B C are preferably constructed so as to form equal halves of the upright box which contains the bedding when the bed is folded, and they may be provided with suitable panels and trimmings to represent the lower part of an ordinary office-desk.

Then folded together, the bed has all the appearance of an ordinary office desk, and may be used

as such. The entire desk, being attached to and forming a part of the head-section of the bed, does not in any way interfere with the folding or unfolding of the bed, and by the novel construction thereof the contents of the desk will be very little deranged by the turning necessary in unfolding the bed.

Having thus described my invention, what I claim, and desire to secure by Letters Patent

I. The combination, with the stationary section A and the folding sections B C, hinged on opposite sides of said stationary section, of a suspended bed-ding-support, h, secured at each end to the respective folding sections B C, the automatic auxiliary

support E. and the jointed braces O, substantially as and for the purpose set forth.

2. The combination with the stationary section A, folding sections B C, and head-board a, of end pieces, c c, top board, d, and cover e, substantially as and for the purpose set forth.

In witness whereof I hereunto subscribe my name this 8th day of November, A. D. 1883.

SARAH E. GOODE.

Witnesses:

PAUL A. Stanley, ARCHIBALD L. Goode

Source: United States Patent Office, Letters Patent No. 322,177, dated July 14, 1885. Application filed November 12, 1883.

Food Preservation

Food preservation is a technique to keep food from rotting after harvest or slaughter. It is used to prevent the rise of bacteria, fungi, or other microorganisms. Among the earliest techniques of food preservation are drying and fermentation. Current techniques include freezing, canning, irradiation, pasteurization, and the addition of chemicals. For example, plain vegetables such as green beans and spinach can cause food poisoning if not preserved the correct way. Pressure-canning these vegetables destroys heat-resistant germs that can cause food poisoning. Advances in packaging have played a significant role in today's methods of food preservation. Maintaining or creating nutritional value, texture, and flavor is a huge aspect of food preservation. Food preservation has become a very important factor in the food industry, since fewer people eat foods that come from their own countries or areas and consumers expect to be able to buy foods that are not in season whenever they would like.

Freezing is the primary method used to preserve food. Clarence Birdseye was the founder of the frozen food industry. Birdseye was an American inventor and entrepreneur born in Brooklyn, New York, on December 9, 1886. Birdseye set out on a five-year trip in Labrador in 1912. While out there, he noticed that Eskimos froze food in the winter because it was hard to gather good-quality food. Birdseye was amazed by their

freezing process, which included ice, wind, and a very cold temperature to freeze fish quickly. He noticed that though the fish was frozen, it was extremely good quality when thawed. He realized that the frozen fish in New York was not comparable to the frozen fish that the Eskimos caught, and with this knowledge, he changed the way food was preserved across the country.

Freezing methods of the time usually used higher temperatures, slowing the freezing process and giving crystals more time to expand. Freezing food faster produces smaller crystals, which cause less damage to it. Birdseye quickly began to wonder how the freezing process worked on other foods besides fish. Back in the United States, he started working on his invention, the "Quick Freeze Machine," which froze food based on the techniques he had learned from the Eskimos. Later, he started his own company, the General Seafood Corporation, which grew and expanded quickly. By the 1930s, the company put out Birdseye's frozen fish, meat, fruit, and vegetables and changed the way people stored, cooked, and ate their food.

Canning is another method used to preserve the food we eat. Canning involves heating food that is sealed in a jar or can to destroy any microorganisms that can cause food spoilage. Air is removed from the jar, and a vacuum is formed as the jar cools and seals. There are two different kinds of canning method. Water-bath canning uses a large kettle of boiling water

to heat the jars, which are held underwater at a temperature of 212°F for a specific period. This method is used to process fruit, tomatoes, pickled food, and high-acid foods. The other method is the pressure-canning method, and it employs a large kettle that produces steam in a closed compartment. The jars in the kettle reach a temperature of 240°F under a specific pressure, with a gauge on the jar cover. This method is used to preserve foods that are low acid, including meat and fish.

Nicolas Appert is the man responsible for the various prepared foods that we now have in grocery stores around the globe. Appert was born on November 17, 1749. He had no formal education but had an interest in food preservation at an early age. He taught himself how to pickle foods and brew beer. Appert was inspired by war when he invented his method. During the late 18th century when French troops took over neighboring countries, it became clear that the government would not be able to succeed if its armies could not transport food on long trips without risk of spoilage. The government offered a prize of 12,000 francs to anyone who could come up with a practical way to fix this issue for the soldiers. Appert was very determined to win this prize regardless of how long it took him.

During this time, there was little or no awareness of food chemistry, so Appert's work was trial and error for some time. His process was to heat foods to the temperature of boiling water using an autoclave, a device that uses steam under pressure to purify food or other items. Appert opened the world's first canning factory in Paris in 1804. In 1809, he was confident in his work of preserving foods and sent his invention to the government.

Appert's process of canning takes about five hours to complete. The food must be placed in sealed glasses that are immersed deep in hot water. With the absence of air, no new germs can get to the food. After the jars are heated, they are removed and sealed shut with corks and sealing wax and then again with wire. The heat kills most of the pathogens that may be in the jars, and it pushes most of the air out of them. This process keeps the food from spoiling for long periods as long as the seals are not broken. Canning is standard for soups, meats, jams, juices, syrups, dairy products, and vegetables.

Another popular method of food preservation, and the oldest, is drying—which involves drying out food at a temperature high enough to take out the moisture but low enough that it doesn't cook the food. In earlier times, drying food in the oven and using the heat of the sun were the most common techniques. But these processes took far too much time and were not always guaranteed.

Chemical pickling is a very popular method of preserving food that places it in an edible liquid that kills germs and other microorganisms. Common pickling aids include vinegar, oil, and alcohol. Many people heat the food that is preserved and then soak it in the aids. Eggs, cucumbers, peppers, and pickles are standard pickled foods.

Food preservation has helped our world prevent decay and spoilage in food, allowing us to store and use it in the future. In some countries, there is a surplus in food production, and in others, there is not enough, so both can benefit from food preservation. Food preservation increases the shelf life for many perishable foods. It is also important because it allows seasonal food to be available to everyone at all times. These methods help prevent the waste of food around the world due to spoilage or decay. They add variety to our meals because we can have many types of food available to us.

Emma E. L. Burke

See also *Vol. 1, Sec. 1: Food Production, Native American; Vol. 2, Sec. 3: Freeze-Dried Food*

Further Reading

- Kurlansky, Mark. 2013. *Birdseye: The Adventures of a Curious Man*. New York: Anchor, Random House.
- Summers, Malcolm. 2015. *Nicolas Appert*. n.p.: Downs Way.
- Wilson, Constance A. 1991. "Waste Not, Want Not": *Food Preservation from Early Times to the Present Day*. Edinburgh: Edinburgh University Press.

Fountain Pen

Lewis E. Waterman's version of the fountain pen, patented in 1884, uses a tube that is reliant on capillary action. The ink flows onto surfaces with ease and with

a fluid motion. Waterman's fountain pen became one of the most successful versions ever on the market. Early models of this pen were made of hard rubber and had 14-karat gold nibs.

Rumor says that the idea for this fountain pen arose when Waterman had to run back to his office after his fountain pen's ink had leaked over a contract he had to sign when he was working as an insurance agent. As he was about to return, one of his competitors took advantage of his absence and closed the deal. This motivated him to create a pen that didn't leak.

Fountain pens already existed then, but Waterman invented a better one. Most fountain pens of the day leaked. He experimented with different tubes and found that capillary tubes managed the ink best. Like all pens, his used gravity to move the ink, but the capillary tube slowed down the movement just enough to prevent it from leaking or spilling.

Just after his patent on February 12, 1884, Waterman sold his handcrafted inventions from the back of a cigar shop with a guarantee that each would last for five years. He also advertised his pens in a popular magazine known as *The Review of Review*. Since business was booming, he decided to expand, and in 1885, he and his business partner, Asa Shipman, founded the Ideal Pen Company. Unfortunately, the company was not successful, and Shipman severed ties with Waterman.

Without a business partner, Waterman made another attempt in his ventures and established the Waterman Pen Company in 1887. There were orders from across the nation and from overseas. Business continued to grow, and there was a large surge in popularity for his pens to the point that production had to be moved. In 1899, he further improved the pen with adjustments that fixed the problem of bubbles that formed whenever ink ran low.

In 1901, Waterman passed away, and the business fell into the hands of his nephew Frank D. Waterman, who continued to expand. About 350,000 sales were made each year, but there were occasional drops when competitors entered the market. The Waterman Pen Company closed in 1954 after some struggles. The French branch of the company, however, survived and became part of the Parker Pen Company in 2001.

Joshua Austria

See also Linotype Machine; Typewriter and QWERTY; Vol. 1, Sec. 3: Pencil Eraser

Further Reading

Lambrou, Andreas. 2003. *Fountain Pens of the World*. London: Philip Wilson.

Steinberg, Jonathan. 2002. *Fountain Pens: Their Art and History*. New York: Universe.

Frasch Process

Mining sulfur fluidically, also known as the Frasch process, is a method invented by Herman Frasch in the 1890s. Before that, extracting sulfur was very difficult. Frasch proudly claimed that he had managed to overcome eight or nine months' worth of effort with three days' worth of process. The Frasch process was the main reason that his company, Union Sulfur, became the main competitor for sulfur extracting companies in Sicily, Italy, in the 1900s.

Sulfur deposits in Texas and Louisiana were accidentally found after attempts to find oil in those states, but they were under quicksand, an obstacle for existing extraction methods. Every attempt to dig for sulfur ended in failure, as quicksand filled any holes soon after they were dug. Frasch, who already had experience in extracting substances, especially oil, decided to try a new method. Sulfur has a melting point of 115.2°C, which is only 15.2°C higher than the boiling point of water, 100°C. Taking advantage of this property, Frasch decided to extract sulfur in liquid form instead of in solid form, which was harder to extract because of the quicksand.

The Frasch process is to drill a hole above a deposit and drop in special pipes before the quicksand can backfill the hole. Frasch's pipes had three layers: the outermost layer was filled with superheated water at 168°C; the melted sulfur would be drawn into the middle layer. However, melted sulfur proved too dense to be pulled out from the pipe, so further heating was necessary to loosen it. Hence, the innermost layer of the pipes was filled with hot air to further loosen the melted sulfur.

The Frasch process reduced the effort and increased the production of sulfur exponentially. He managed to

significantly reduce the time spent to extract the element, which had earlier been taken up by attempts to remove quicksand. A single well using the Frasch process outproduced the several hundred existing wells in Sicily that still used the old methods; as a result, Union Sulfur became the second biggest producer of sulfur in 1904 and dominated the sulfur industry.

When the patents for the Frasch process expired in 1908, many other companies appeared in the industry, increasing the competition. They are generally called Frasch companies because they all use the Frasch process. New Frasch companies appeared mainly because they were able to mine deposits that existing companies deemed too small. Even these small deposits allowed them to become serious competitors by using the Frasch process.

The Frasch process of mining sulfur fluidically completely revolutionized the sulfur industry and, in addition, created a new more competitive and globalized sulfur market.

Wai L. Phyoo

See also *Vol. 1, Sec. 3: Coal-Mining Technologies; Gold-Mining Technologies*

Further Reading

Kutney, Gerald. 2013. *Sulfur: History, Technology, Applications & Industry*. Toronto: ChemTec.
 “Sulfur Mining.” 1929. *Journal of Chemical Education* 6, no. 1: 129.

Gas Transmission

In the 1880s, natural gas was a promising source of energy. George Westinghouse resided in Pittsburgh, a city seated on an abundance of natural gas. He contemplated how he could control it in the same way he had invented the air brake that controlled compressed air in trains. He developed a way to distribute gas in Pittsburgh after drillers had broken into a flow of natural gas in his backyard.

Despite the public’s fear of natural gas due to the potential danger of occasional explosions, Westinghouse found it intriguing. He hired workers to drill in his yard, and soon a burst of sand, dirt, and water

spewed from the ground. The volcanic eruption of debris soon weakened, and a steady stream of gas gushed out of the well. Westinghouse had to quickly think of a way to control it before further chaos ensued; he responded by developing a simple valve. Later, he had to take further action and implemented the use of a 60-foot-long pipe. Because of how dangerous the substance was, there were horrific moments where Westinghouse shot fire into the sky.

In the summer of 1884, he received his first major patent for a system to utilize and keep gas under control while it was under high pressure. After establishing the Philadelphia Company, he patented 38 new inventions that were related to piping, especially ones related to natural gas, in 1884 and 1885. He found better ways to dig wells, invented meters for measuring the gas, and preventative methods against leaks.

Using a design similar to that of his patented automatic air brake, one of his most important patents made operations with natural gas much safer. It was for an automatic mechanism that shut off the flow of gas once a certain pressure was reached. After that, the supply of gas continued at the push of a button by an operator.

Another useful piping mechanism that he invented allowed for a healthy distribution of gas to both public and industrial consumers. Because the pressure of gas is naturally strong and usually too high to use directly, he designed a pipe system that stretched for miles. The pipes were narrow but widened at certain intervals, reducing the pressure of the gas based on the time of use. This piping infrastructure was recognized as the first widespread natural gas delivery system.

With Westinghouse’s Philadelphia Company as the main supplier for Pittsburgh’s natural gas, he had realized the business potential for the substance. The Equitable Gas Company later became a subsidiary. Westinghouse became the ruler of the gas industry.

He then applied his knowledge of natural gas technology to develop the alternating current distribution system for electricity, another seminal innovation.

Today, natural gas is one of our most important and affordable resources. The technology that Westinghouse created made it easier for us to work with it: the dangers have decreased as efficiency has increased.

Joshua Austria

See also AC Generator and Transformer; Westinghouse Air Brake; *Vol. 3, Sec. 1: Liquefied Natural Gas (LNG) Carrier*

Further Reading

Leupp, Francis E. 1918. *George Westinghouse: His Life and Achievements*. Boston: Little, Brown.

Prout, Henry G. 2005. *A Life of George Westinghouse*. New York: Cosimo Classics.

Skrabec, Quentin R., Jr. 2006. *George Westinghouse: Gentle Genius*. New York: Algora.

Waples, David A. 2012. *The Natural Gas Industry in Appalachia: A History from the First Discovery to the Tapping of the Marcellus Shale*. Jefferson, NC: McFarland.

General Electric

General Electric (GE) is one of the largest American industrial corporations in the world. Founded in 1892 after a merger of Edison General Electric Company and Thomson-Houston Electric Company, the new company had its headquarters in Schenectady, New York. The company is currently located in Boston, Massachusetts. GE's operations are located in more than 170 countries and employ about 300,000 people. It primarily offers electronic and electrical equipment, aircraft engines, and financial services.

The company was originally founded as the Edison General Electric Company, one of the many companies that Thomas Edison founded or had interest in. J. P. Morgan and Anthony Drexel, both financiers, put together the deal first to merge Edison's electric companies into one and then to merge that company with Thomson-Houston. The newly consolidated company solved the major problem facing small electrical companies: that it was difficult to fund electric installations with their own patents and technologies. The company proved so successful that in 1896, it was one of the first 12 companies listed in the Dow Jones Industrial Average. It is the only original company still listed on the Dow index.

In 1900, GE created the first laboratory used for scientific research in the United States. Since then, many new inventions and ideas have come from GE's research labs, including the electric fan, voice radio broadcasting, the electric stove, the hermetically sealed refrigerator, "invisible glass," the electric locomotive, the Hotpoint range, the jet engine, the vacuum tube, the autopilot, the commercial use of radar, and the nuclear power plant.

Electrical devices changed society significantly, pushing the steam age of the 19th century into the electrical age of the 20th century. Many of GE's technological innovations fundamentally changed the way Americans lived. For example, the incandescent lightbulb used in cars and trains allowed for safe night



An aerial view of the General Electric Company buildings in Schenectady, New York, ca. 1907. The company was founded on April 15, 1892. (Library of Congress)

travel. Radio broadcasting became mainstream entertainment in the mid-20th century.

GE owns a plethora of corporations that focus on different operations. The list includes GE Aviation, GE Capital, GE Digital, GE Energy Connections, GE Healthcare, GE Lighting, GE Power, GE Renewable Energy, GE Global Research, and GE Transportation.

General Electric has been awarded and recognized in significant ways. The company has been ranked in lists such as the World's Most Admired Companies, the World's Most Valuable Brands, the World's 100 Most InDemand Employers, the Top Companies for Leaders, the Best Companies for Leadership, the World's Most Ethical Companies, the Best Companies for Working Mothers, and the Top 50 Employers for Women. Nonetheless, in the late 20th century, GE gained fame for its ruthless corporate restructuring, giving rise to a national trend for downsizing and laying off employees. GE also found itself embroiled in price-fixing scandals and was cited on numerous occasions for breaking Nuclear Regulatory Commission rules.

Lusine Davtyan

See also Edison, Thomas; Electric Lightbulb; *Vol. 1, Sec. 3*: Electric Stove; Electric Street Railway; *Vol. 2, Sec. 2*: Radio; Washing Machine, Electric

Further Reading

O'Boyle, Thomas F. 1998. *At Any Cost: Jack Welch, General Electric and the Pursuit of Profit*. New York: Knopf.

Goodrich, B. F. (1841–1888)

Benjamin Franklin Goodrich, a physician and industrialist, founded several rubber businesses, including the B. F. Goodrich Company (1880). Goodrich faced failure on several occasions, but his persistence helped his company survive. More important, Goodrich built a company dedicated to technological innovation. In fact, the formative years of the automobile, airplane, and space industries benefited from B. F. Goodrich's innovations.

Goodrich was born in Ripley, New York, on November 4, 1841. He graduated from Cleveland Medical College in 1861, and he worked as an army surgeon during the American Civil War (1861–1865). He resigned from the army in 1864 and practiced private medicine for about a year. In 1866, he left the medical profession permanently and entered the real estate business in New York City.

In 1867, he and J. P. Morris, his real estate partner, purchased the Hudson River Rubber Company. Neither man knew anything about the production of rubber, but they saw the purchase as a money-making opportunity. Goodrich learned about the rubber industry on the job. Unfortunately, due to worn-out mechanical equipment, the company failed. But the failure did not deter Goodrich. Still convinced of the great future of rubber, the partners purchased another rubber company in Melrose, New York, in 1868.

Due to intense competition, his second company was also in danger of failure. To save it, Goodrich moved it away from competitors to Akron, Ohio, in 1870 and named it Goodrich, Tew & Company (GTC). GTC focused mostly on producing fire hoses, billiard cushions, and belting, and it struggled financially for almost a decade. In an attempt to keep GTC alive, Goodrich infused it with capital from new investors and reorganized and renamed it Goodrich & Company in 1874 and then B. F. Goodrich Company (BFG) in 1880. Goodrich ran the company as both president and manager. But the work was too much for him, and it placed a strain on his health. He died on August 3, 1888, in Manitou Springs, Colorado. But the company survived.

An American bicycle fad and the rise of the automobile industry in the late 1800s provided BFG with profitable tire markets. In 1895, BFG established the rubber industry's first experimental research laboratory. Innovation led to new products for consumers and financial success for BFG. Some of its innovations included the first pneumatic (inflatable) tire for bicycles (1890), the first pneumatic tire for automobiles (1897), the first rubber sponge (1902), the first cord tire for automobiles (1910), the first synthetic rubber tire for automobiles (1945), and the first radial automobile tire (1965).

BFG was also a major producer of aircraft tires. For example, all World War I (1914–1918) American

aircraft used BFG tires. After World War II (1939–1945), BFG expanded its research and development focus to aerospace (aviation and space flight technology). Alan Shepard, the first American in space, wore a space suit designed by BFG.

Rolando Avila

See also *Vol. 1, Sec. 1*: Franklin, Benjamin; *Vol. 1, Sec. 3*: Goodyear, Charles; Vulcanization

Further Reading

Collyer, John Lyon. 1952. *The B. F. Goodrich Story of Creative Enterprise, 1870–1952*. New York: Newcomen Society, American Branch.

Goodyear, Charles, Jr. (1833–1896)

Charles Goodyear Jr., a businessman, was the oldest son of Charles Goodyear (1800–1860), the inventor of vulcanized rubber. Besides helping his father with his rubber business, he helped launch the mechanized shoe industry. Much more of a business innovator than an inventor, Goodyear's contributions to shoemaking were significant.

Goodyear was born in Germantown, Pennsylvania, on January 1, 1833. His father's obsession with finding a way to vulcanize rubber rather than earning a daily wage left the family destitute. However, after many attempts, his father was successful, and he patented his invention in 1844. Goodyear learned about the power of innovation from watching his father, and he learned about business by helping him sell licenses to manufacturers so that they could legally use the same process for making rubber. He also helped his father make, sell, and distribute rubber goods. After his father died in 1860, Goodyear spent the rest of his life overseeing Goodyear rubber patents, which generated income.

In addition, Goodyear extended his business interests to shoemaking. Handmade shoes were expensive because the process was time-consuming and labor-intensive. The earliest attempts to incorporate machines into shoemaking (driven by human hand or foot power) did not significantly increase production. By the mid and late 1800s, however, thousands of patents had been granted, and a variety of steam-powered and electric

machines were in use. Many inventors had attempted to adapt sewing machine technology to shoemaking. Unfortunately, most of the inventions suffered from performance flaws and frequent breakdowns. Goodyear saw a business opportunity, and he embarked on a mission to build and sell improved shoemaking machines. He began by purchasing the rights to several patented machines and then hired skilled inventors to improve them. By the 1870s, Goodyear had built factories of the Goodyear Boot & Shoe Machinery Company in both England and the United States. But innovation was expensive and, unfortunately, his company was not able to sell enough machines to make a profit until after his retirement in 1888.

Perhaps his greatest contribution in the shoe industry was overseeing the production of the Goodyear shoe welt machine. Several shoemaking processes were common, but handmade welt shoes were among the most expensive and typically custom made for the wealthy. A welt (usually made of leather) served as an attachment point for the sole of a shoe. His process made it possible for shoemakers to resole shoes and extend the lifespan of shoes by years. Goodyear's machine cut the price of producing welt shoes dramatically (from about 70 cents a pair to about 10 cents). In short, Goodyear's improved machines revolutionized the shoe industry by making it possible to mass-produce better shoes at lower prices. In poor health the last years of his life, Goodyear died on May 22, 1896.

Rolando Avila

See also *Vol. 1, Sec. 3*: Goodyear, Charles; *Vol. 3, Sec. 1*: "Air" Athletic Shoes

Further Reading

"Charles Goodyear Obituary." 1896. *New York Times*, May 23.

Gannon, Fred A. 1912. *A Short History of American Shoemaking*. Salem, MA: Newcomb & Gauss.

Hallidie, Andrew Smith (1836–1900)

Andrew Hallidie invented the cable car, a motorless vehicle pulled along a track by a strong cable rotated off board by a powerful motor, in San Francisco around

1873. He was born in London on March 16, 1836. His grandfather was an educator from Scotland and a soldier during the Napoleonic wars, and his father, Andrew Smith, owned the patent for wire rope cable.

Hallidie's training was of both mechanical and scientific character. At only 10 years of age, he successfully constructed an electrical machine. At 13, he began working closely with his brother in a machine shop, and in 1852, they left for the United States. However, the father returned to England in 1853 while Hallidie remained in California, engaging in odd mining jobs. During this period, he designed several types of machinery to make mining work easier.

Hallidie abandoned mining in 1857 and returned to San Francisco with some of the machinery he had built. He began designing suspension bridges and became famous. In 1867, Hallidie obtained his first patent for the invention of a rigid suspension bridge. More patents followed. In 1871, he completed plans for propelling streetcars using underground cables. The first cable car was eventually tested on August 2, 1873. On April 24, 1900, Hallidie died of heart disease at his San Francisco residence as one of the city's most distinguished citizens.

Cable cars became popular due to their extraordinary capabilities. The cars overcame particular challenges, crossing waterways with minimum infrastructure as compared to other modes of transport such as buses and railways. Constructing transport infrastructure through such a terrain is costly, and cable cars solved the problem, as they could easily pass over mountains and steep slopes. The unique ropes used by the system could easily blend with the environment. Thus, the surroundings were only slightly affected and retained the beautiful scenery that was a tourist attraction. Additionally, they were more convenient compared to horses, which worked for only a few hours and had to be fed, receive medication, and rest, among other obligations.

In 1947, Mayor Roger Lapham decided to forbid all cable car lines to minimize operation costs. His intention was prompted by the growing popularity of buses, which appeared to be cheaper in terms of maintenance. A lobbying group began a public campaign to mobilize stakeholders and city leaders by emphasizing the importance of cable cars. In their argument,

they suggested that the intrinsic value to San Francisco was higher compared to operational costs. Finally, they succeeded, and an amendment was made on the ballot entitled Measure 10. City newspapers covered the story widely. Additionally, the lobbyists received overwhelming support from the public, and celebrities all over the country supported their brilliant move. The business community agreed, adding that cable cars were one of the most popular tourist attractions in the city.

Rosanne Welch

See also Vol. 2, Sec. 2: Automobile Technologies (Pre–World War II)

Further Reading

Hilton, George. 1997. *The Cable Car in America*. Redwood City, CA: Stanford University Press.
Smallwood, Charles. 1987. *The Cable Car Book*. New York: Random House Value.

Harvard Computers

Also known as Pickering's Harem, the Harvard Computers were a group of women hired to process astronomical data for Edward Charles Pickering at the Harvard College Observatory. The moniker "Pickering's Harem" was a reflection of the consideration for female intellect at the time, since the Harvard Computers were viewed as secretaries rather than scientists in their own right. Their work was integral to the completion of the Henry Draper Catalogues. Their examinations of photographs taken by the Observatory's male astronomers (a field now known as astrophotography) led to many discoveries and laid the empirical foundations for larger astronomical theory.

Edward Charles Pickering was the director of the Harvard College Observatory from 1877 to 1919. He was tasked with completing the work of Henry Draper, which focused on a catalogue of all the stars in the visible sky. By 1881, Pickering realized that the volume of data coming into the observatory in the form of photographs of the night sky was exceeding his staff's ability to analyze and catalog. A progressive thinker in

terms of educational opportunities for women and, frustrated with male staff members, Pickering hired his maid, Williamina Fleming, to help catalog the photographs taken by astronomers in the observatory. Fleming had been a teacher before having a child and becoming a maid. She proved highly adept at the task of performing careful and precise calculations and developed a system of classifying stars by using letters to designate how much hydrogen could be seen in a star's spectrum, which became known as the Pickering-Fleming system.

In 1886, Anna Mary Palmer Draper, the widow of Henry Draper, made a generous donation to the Harvard College Observatory. Pickering used the money to hire a group of female computers to work under Fleming's direction. The group of women was tasked with finishing Draper's catalogue by scanning and measuring astronomical photographic plates and completing calculations on the positions and brightness of stars. The group—which included Annie Jump Cannon, Henrietta Swan Leavitt, and Antonia Maury—worked in a large room on the east end of the Harvard College Observatory's top floor. Between 1881 and 1919, more than 80 women were hired to compute and catalog data, many of whom were recent high school or college graduates. The women worked six days a week, seven hours a day, earning 25 to 50 cents per hour—less than most clerical workers of the time. Their duties included reducing the photographs, taking into account things like atmospheric refraction to render the images as clear as possible; cataloging the photos; making notes on exposure and regions of the sky, which were copied into tables to record the locations and magnitudes of stars; and measuring the brightness of stars (spectra) to determine the properties of celestial objects.

As a result of their work, Pickering was able to complete and publish the first Henry Draper Catalogue in 1890. The catalogue included more than 10,000 stars classified according to their spectra. Two decades later, the catalogue was revised to include new observations. The Henry Draper Catalogue was republished every year from 1918 to 1924. Ultimately, the Henry Draper Catalogues classified over 50,000 stars by temperature, which indicated the size and age of the star.

Though the Harvard Computers received almost no recognition during their lifetimes, they surpassed most of their male counterparts in their discoveries in astronomy and astrophotography. They also wrote and performed a play called the *Observatory Pinafore*, a spoof based on newspaper articles of their work and fashioned after the play *H.M.S. Pinafore*. The play was performed on December 31, 1929, and included Cecilia Payne, Henrietta Swope, Mildred Shapley, Helen Sawyer, Sylvia Mussels, and Adelaide Ames.

Many of the Harvard Computers went on to stake individual claims to fame in astronomy. Williamina Fleming, the original computer, became the first female curator of astronomical photographs at Harvard College Observatory in 1898, and the fifth woman and first American woman to become honorary member of the Royal Astronomical Society of London in 1906. Her discoveries included the Horsehead Nebula, over 10,000 stars, and the existence of white dwarf stars. Antonia Maury developed a classification system that anticipated the connection between temperature and luminosity, now called the Hertzsprung-Russell diagram, and became the first woman to have her name on the cover of the Harvard Annals. Annie Jump Cannon expanded on Fleming and Maury's work to develop the OBAFGKM classification system for stars, also known as the "Harvard classification scheme," which is still in use today. Henrietta Swan Leavitt's observations led to the discovery of a direct relationship between the period of Cepheid variable stars and their intrinsic brightness, leading to our modern understanding of the true size of the universe and tools for measuring cosmological distance. Her work also identified 1,200 variable stars and enabled astronomers to calculate how bright a star should be to determine its distance from earth.

Together, the work of the Harvard Computers served as the statistical basis for theoretical astronomy. Many of their individual accomplishments are integral to our understanding of the universe and nature of stars today. The photographic plates and catalogs created by the Harvard Computers are still used by astronomers today, and their work helped to establish the Harvard College Observatory as a well-respected observatory and program.

Though the Harvard Computers remain relatively unknown, their work powerfully suggests the value of women scientists.

Tiffany Rhoades

See also *Vol. 2, Sec. 2*: Cannon, Annie Jump

Further Reading

Johnson, George. 2006. *Miss Leavitt's Stars: The Untold Story of the Woman Who Discovered How to Measure the Universe*. New York: W. W. Norton.

Nelson, Sue. 2008. "Big Data: The Harvard Computers." *Nature* 455 (September): 36–37.

Primary Document: Undated Photo of the Harvard Computers

At the far left in this photograph is Margaret Harwood, who was later appointed director at the Maria Mitchell Observatory, thus becoming the first woman to be appointed director of an independent observatory.

Source: Observatory Group, ca. 1910. HUPSF Observatory (14), olvwork360662. Harvard University Archives.



Haynes, Elwood (1857–1925)

American inventor Elwood Haynes manufactured early automobiles and patented martensitic stainless steel in 1913. His automobile design is widely credited with being the first practical for mass production.

Haynes was born in October 14, 1857, to parents of English descent. He grew up in Portland, Indiana. Haynes's father was the local school commissioner, a lawyer, politician, and judge of the local county. Haynes's mother, a devoted Presbyterian, staunchly supported the prohibition of alcohol. Haynes's interest

in metallurgy came from his grandfather, Henry Haynes, who was a gunsmith and mechanic. With a move to the countryside of Indiana, Haynes could build a melting furnace with the help of his grandfather. Some of the metals Haynes experimented with were copper, bronze, and iron. When not experimenting with his furnace and alloys, Haynes was often found exploring the woods near his house and surveying the various plants and animals. He spent so much time outdoors that his parents nicknamed him “Wood.”

Haynes began his career as a superintendent for Indiana gas and oil companies. In the 1890s, like many American mechanical entrepreneurs, he began to work on automobile development. Haynes initially hoped to have a steam-powered vehicle but found too many limiting factors connected with how the vehicle would generate power, and he ultimately abandoned the plan for more practical and proven techniques. To power his new vehicle, Haynes ordered a two-cycle engine from the Stintz Gas Engine Company for \$255. This type of engine was primarily used in small boats, but Haynes found that he could adapt it to provide power to turn tires in an automobile. Initially Haynes wanted to use lightweight materials such as leather and wood to fabricate the carriage so that the most power could be derived from the engine. However, he found these materials were not rigid enough to stop the vibrations from the two-cycle engine and did not provide enough rigidity. Haynes leveraged his knowledge in metallurgy and could craft a new carriage comprised primarily of steel. He test-drove his car, named Pioneer, in July 4, 1894, in the town of Kokomo, Indiana.

Haynes formed a partnership with Elmer and Edgar Apperson in 1896 to create Haynes Automobile Company. Haynes applied his attention to the problem of metal corrosion in automobile manufacturing, mixing tungsten with chromium, steel, and iron. He named this new alloy “Stellite.” In 1912, he founded the Haynes Stellite Company.

Stainless steel proved to be a highly versatile alloy, useful in many different applications. Stainless steel beams gave buildings a stronger structural frame, allowing them to achieve heights that proved too structurally difficult for lesser metals. One of the characteristics of stainless steel was that it could keep its rigidity in higher temperatures, and therefore kept its shape

under stress. This ability was highly sought after by the railroad companies because they wouldn’t need to replace tracks as often. Industrial infrastructure was not the only application for stainless steel. Many utilitarian purposes in the consumer space were enhanced by a corrosion-resistant alloy. Such household items as pans, knives, and forks could reap the benefits. These resistant properties would prove to be very alluring for the downstream consumer, because this meant that they wouldn’t need to buy new household items as often. World War I demand for his metal alloy made Haynes a millionaire.

Elwood Haynes passed from congestive heart failure on April 13, 1925, in Jacksonville, Florida. Before his death, he was recognized for notable contributions to industry, but chief among those accolades was the gold medal he received for his work with the Apperson brothers, awarded by the National Automobile Chamber of Commerce of New York. It was while traveling on the award trip that Haynes contracted influenza. His accomplishments in the advancement of the American auto industry will forever be recognized. It only seems fitting that Haynes’s funeral and burial took place in Kokomo, Indiana, where he first test-drove his model automobile, Pioneer. He left such an influential and lasting impact on the state of Indiana and the auto world that the General Motors Company used his family mansion as a headquarters for many years. The mansion is now in the possession of the city of Kokomo and houses the Elwood Haynes Museum.

Peg A. Lamphier

See also *Vol. 1, Sec. 2: Steam Engine; Vol. 1, Sec. 3: Railroads; Vol. 2, Sec. 2: Automobile Technologies (Pre–World War II)*

Further Reading

Gray, Ralph. 2002. *Alloys and Automobiles: The Life of Elwood Haynes*. Bloomington, IN: Guild Press, Emmis.

Heyl, Henry (1842–1919)

Henry Heyl is best known as the inventor of the modern stapler, a fastening device that drives thin metal staples through paper and folds the ends. This device

is now common in offices throughout the world and helps facilitate all manner of business. Heyl also invented an early movie camera called the “phasmatrope.”

Henry Heyl was born in Columbus, Ohio, in 1842 and became a member of the Franklin Institute, a science and education center in Philadelphia. He raised four children with his wife, Mary Knauff. Some of his other inventions of note are the phasmatrope, which was a glass tube that, using static electricity, could project illusions onto a screen. What was so notable about this invention was that it was one of the first instances in which a succession of photographic sequences could be interpreted as motion. Heyl’s work could have been one of the precursors to film.

In 1882, Heyl filed patent number 83,640 with the U.S. Patent Office, entitled “Improvement in Paper Fasteners.” As noted in the title of the patent, Heyl’s invention was not something uniquely new but an improvement on a device that had already been in use since the 1700s. Originally, the stapler, developed in France, was used to place ornate handmade staples on documents of the royal court. However, Heyl’s patent was for the first device that could simultaneously punch through a stack of paper, insert a wire staple, and clinch the staple by bending the ends inward. Thus, the advantage of Heyl’s design was that it could complete a series of three motions in one action. Through the bending of the staple legs, stacks of papers could now be held together in an organized fashion, enabling the user to be able to quickly cycle through documents without compromising the sequential integrity of the documents or the documents themselves.

In the 1870s, Heyl filed patents for paper boxes and a camera that created the illusion of motion he called the Phasmatrope. The Phasmatrope used sequenced glass transparencies mounted on a disk fitted with a shutter to create pictures of a couple waltzing. He presented his invention at the Philadelphia Academy of Music in February 1870, and again a month later at the Franklin Institutes. Heyl’s Phasmatrope and its projected photographic sequence can be considered a forerunner to the moving picture or movie camera.

Heyl died in 1919. While his Phasmatrope is considered an important step in the history of moving pictures, he is best remembered as the inventor of the modern stapler.

Brian Lugo

See also Office Technology (Pre–World War II); Paper Clip; Vol. 2, Sec. 2: Scotch Tape

Further Reading

Ward, James. 2015. *The Perfection of the Paper Clip: Curious Tales of Invention, Accidental Genius, and Stationery Obsession*. New York: Touchstone.

Ice Cream Soda

The history of ice cream soda is a dubious one, with several people claiming they invented the concoction. Some speculation dates back to 1862, when Philip Mohr claimed that he mixed soda water and ice cream to cool the drink. However, the commonly accepted originator, who also worked to popularize the drink, is Robert M. Green. In 1874, at the Semi Centennial Celebration at the Franklin Institute in Philadelphia, Green had been selling soda, which was a combination of carbonated water, sweet cream, and syrup. He unexpectedly sold out of cream and had to turn to ice cream instead. It was a massive success, multiplying Green’s sales 100 times over.

The evolution of the ice cream soda has shifted over time, with dozens of alterations. In the 1890s, some members of the church urged against drinking soda on the Sabbath day (Sunday) because of the glutinous way people ingested it. Thus, on Sunday, stores began serving their ice cream without soda but kept the syrups, leading to the popular ice cream alternative called the “sundae.”

Cassady O’Reilly-Hahn

See also Vol. 1, Sec. 3: Hand-Cranked Ice Cream Maker

Further Reading

Geist, Edward. 2012. “When Ice Cream Was Poisonous: Adulteration, Ptomaines, and Bacteriology in



A soda jerk serves an ice cream soda in 1936, though the sweet treat dates back to 1874, when Robert M. Green ran out of cream for one of his drinks and used vanilla ice cream instead. (Library of Congress)

the United States, 1850–1910.” *Bulletin of the History of Medicine* 86, no. 3: 333–60.

Harwood, Meriel L., Joseph R. Loquasto, Robert F. Roberts, Gregory R. Ziegler, and John E. Hayes. 2013. “Explaining Tolerance for Bitterness in Chocolate Ice Cream Using Solid Chocolate Preferences.” *Journal of Dairy Science* 96, no. 8: 4938.

Skinner, W. 1922. “Bottled Beverages and Soda Fountain Sirups.” *American Journal of Public Health* 12, no. 6: 487–93.

Inman, George (1895–1972)

George E. Inman led a group of scientists who produced the first commercial fluorescent lamp in 1935. Inman worked for General Electric lighting laboratories in Cleveland, Ohio. He was issued patent number 2,259,040 for the fluorescent lamp on October 14, 1941, with a filing date of April 22, 1936. To speed up the process, he used the design of an existing tubular

incandescent lamp. European competitors and rival companies Westinghouse and Sylvania were also working on fluorescent lighting. In 1934, General Electric Co. Ltd. in London, unrelated to the American General Electric Company, had come up with an experimental green fluorescent lamp with a brightness of 35 lumens per watt. The news of the European company’s progress pushed the development of the GE labs in the United States.

Some companies had filed patents already, but GE kept control by buying a German patent that preceded Inman’s patent. GE paid \$180,000 for patent number 2,182,732, which had been issued to Friedrich Meyer, Hans J. Spanner, and Edmund Germer. Edmund Germer had successfully made a fluorescent lamp that emitted white light, unlike other previous experiments that emitted blue-green light. While other companies had fluorescent lamps on the market by 1938, none were as well received as GE’s fluorescent lamp. There may be arguments about who the actual inventor of the fluorescent lamp is, but GE with Inman were the first to introduce it to the market.

Inman’s fluorescent lamp, which used white phosphors, was stable and reliable. The fluorescent lamp designed by Inman was a long tube filled with gas at low pressure. As the electricity flowed through it, it excited the gas, causing ultraviolet light to be emitted. The cylindrical bulb is coated with a film that then turns the ultraviolet light into white light. Mercury vapor and a gas, usually argon, are now commonly found in the compact fluorescent lightbulbs (CFLs) that we use in our houses.

George E. Inman’s work continues to be used today. The first fluorescent lamps might have appeared in 1938, but today, CFLs are used all around the world. Light-emitting diode (LED) lights are also available, but the reliability, lamp life, and cheap production as well as energy efficiency of fluorescent lamps cause them to be one of the most common lighting choices.

Joshua Drewry

See also Edison, Thomas

Further Reading

Butler, Keith H. 1980. *Fluorescent Lamp Phosphors: Technology and Theory*. Philadelphia: Pennsylvania State University Press.

- Funke, J., et al. 1959. *Fluorescent Lamps and Lighting*. n.p.: Philips Technical Library.
- Hein, Martin G. 2013. *Lamp Design after the Light Bulb: Luminaires with LEDs and Compact Fluorescent Lamps*. 2nd ed. CreateSpace Independent Publishing Platform.

Iron Ship with Revolving Turret

Swedish-born inventor John Ericsson was responsible for the completion of the USS *Monitor*, the first iron ship with a revolving turret. The *Monitor* fought at the battle of Hampton Roads on March 8, 1862, during the American Civil War against the CSS *Virginia*. The design of the ship was one that most people had never seen before; it looked nothing like ships that had fought previously. Its construction and innovative design changed the way that the U.S. Navy would construct its future naval ships forever.

John Ericsson was born July 31, 1803, in Värmland, Sweden, to a modest family. Ericsson, along with his brother Nils, were self-taught mechanics. They had never had any type of training or schooling prior. When Ericsson turned 17, he joined the Swedish Army, where he received training in various skills. In 1826, Ericsson moved to England after leaving the army. He began to pursue different engineering projects, and he became quite a popular engineer and inventor. Ericsson moved to New York City in 1839, where he began to work on the first U.S. Navy screw-powered warship, which became to be known as the USS *Princeton*.

On October 4, 1861, the U.S. Navy signed a contract that granted Ericsson only 100 days to complete the construction of the USS *Monitor*. The ship was officially launched for sail on January 30, 1862. Many ships built prior to the *Monitor* had been constructed with turrets but never any that were capable of rotating. Turrets were designed to protect crew members and to mount weapons, but with the design of the turret on the *Monitor*, it was now possible to block cannon shots because of its rounded shape, as well as to maneuver guns on board much more easily.

The *Monitor* was a ship designed like no other. It was 172 feet long, and from the beam, it was 41.5 feet. The hull was five-eighths of an inch thick, being heavily armored and protected from cannon fire. The gun turret on the deck was quaint but very protected, as it

had a removable smokestack and a small pilothouse. Eight layers of one-inch, iron-bolted plate held the turret together. A sound barrier was also provided inside the turret with the addition of a ninth layer of plate. Many of these components would later be introduced into submarine design.

On March 8, 1889, Ericsson died on the anniversary of the Battle of Hampton Roads. He was forever immortalized as one of the greatest naval engineers in the United States and most recognized for his work on the *Monitor*, although he engineered other inventions as well.

The *Monitor* revolutionized naval ship building by combining speed with armor defense in the same ship. This ship allowed for a more precise and strategic construction of new ships built for the naval forces. Many engineers and designers began to copy the design of the *Monitor* for their own warships. The rotating turret can be found on modern warships and is a valuable technological creation in naval history.

Melissa Lopez Gutierrez

See also *Vol. 1, Sec. 3:* Clipper Ship; *Vol. 2, Sec. 3:* Liberty Ships

Further Reading

- Broadwater, John D. 2012. *USS Monitor: An Historic Ship Completes Its Final Voyage*. Ed Rachal Foundation Nautical Archaeology Series. College Station: Texas A & M University Press.
- Greene, Jack, and Alessandro Massignani. 1998. *Ironclads at War: The Origin and Development of the Armored Warship, 1854–1891*. Conshohocken, PA: Combined.
- Mindell, David A. 2000. *Iron Coffin: War, Technology, and Experience aboard the USS Monitor*. Baltimore: Johns Hopkins University Press.

Ironing Board

The ironing board had its last major improvement in 1892, when African American inventor Sarah Boone was granted a patent on an improved design. Prior to Boone's improvement, W. Vandenburg had patented an ironing table in 1858. Boone's improvements made it much easier to iron sleeves, collars, and women's more intricately shaped garments.

Boone was born Sarah Marshall in 1832 on a plantation in North Carolina. During this time, North Carolina was not considered a free state, and the exact date of her birth is unknown. She married James Boone, who was a freedman with whom she had eight children. Before the American Civil War could begin, the family decided to move to New Haven, Connecticut. She became a dressmaker, and her husband worked as a brick mason.

As a dressmaker, Boone often found it hard to iron many of the garments, since the tools that then existed would not adapt to the different clothing she was handed. Boone decided to invent an ironing board that would make it possible for her to finally iron garments properly. The ironing board she created was a curved, narrow wooden board that made it possible to iron all sides of a garment.

On April 26, 1892, the U.S. Patent and Trademark Office issued Boone U.S. Patent 473,655 for the improvement of the ironing board. This was a great accomplishment for Boone, as she was one of the only African American women during this time to be granted a patent.

The improvements to the board made ironing quicker and more precise. The curves that Boone added remain in the versions still manufactured today. Two changes have been made to the ironing board since. The first is that the boards are no longer of wood but rather of metal. Making them is faster, and they last longer. The second change is that they are narrower and can fit practically anywhere. There are also half-sized boards that rest on tabletops, making storage easier for people living in smaller spaces and making small ironing jobs simpler.

Although modern fabrics have eliminated much of the need for ironing and therefore ironing boards, Boone's improvements changed the way that people ironed clothes for many decades. Boone died in 1901.

Melissa Lopez Gutierrez

See also Vol. 2, Sec. 2: Washing Machine, Electric

Further Reading

Holmes, Keith C. 2008. *Black Inventors: Crafting Over 200 Years of Success*. New York: Global Black Inventor Research Projects.

McKissack, Pat, and Fredrick McKissack. 1994. *African-American Inventors*. A Proud Heritage. Brookfield, CT: Millbrook Press.

Sullivan, Otha Richard. 1998. *African American Inventors*. Black Stars. New York: Wiley.

Jeans

If there is one single item of clothing that epitomizes the American way of life and culture more than any other, it is undeniably jeans. Once primarily regarded as the outfit of those who worked hard for a living, nowadays, they are a staple item in wardrobes worldwide, irrespective of gender, social class, economic background, economic considerations, or culture.

Jeans were originally the invention of German immigrant Levi Strauss (1829–1902). In 1848, Strauss moved to New York City with his mother and sisters to work at the dry goods stores that his two elder brothers already owned on Houston Street: “J. Strauss Brothers & Co.” (which would be renamed “Levi Strauss and Co.” in 1863). In 1853, he moved to San Francisco to open a branch of his brother’s shop with the aid of his brother-in-law, David Stern.

Despite the long-held belief (further reinforced by a pervasive Levi’s promotional campaign) that jeans were primarily designed with those attracted to the California Gold Rush in mind, the truth is that they were not produced until years after the peak of the Gold Rush. In San Francisco, Strauss realized that pants did not last long enough due to hard working conditions. Strauss’s first waist overalls were made of canvas, although he later decided to make them out of “*serge de Nîmes*” (what we know today as “denim”).

A Nevada tailor, Jacob Davis, perfected the pants made of Strauss’s cloth by adding metal rivets, but lack of funds prevented him from patenting his system. Davis next approached Strauss and offered to share the patent in exchange for Strauss’s coverage of the fees to apply for the patent. It would be on May 20, 1873, that they were jointly granted U.S. Patent 139,121.

The first jeans were either indigo blue or brown cotton (called “duck”), but the latter was soon discontinued. The blue color was the creation of chemist



Marlon Brando and his gang from *The Wild One* (1953), decked out in “bad boy” jeans. While jeans are currently considered mainstream clothing, in the 1950s they were a symbol of rebellion. (John Springer Collection/Corbis via Getty Images)

Adolf von Baeyer, who invented synthetic indigo dye, which earned him a Nobel Prize. Strauss’s pants were known until 1890 as “waist overalls.” In 1890, the same year that Strauss and his nephews incorporated the business, they were renamed “501s.” In the 1960s, they began to be called “jeans,” which is derived from the name of Genoa, the Italian city where the fabric originated. The use of the name “Levi’s” to refer to the jeans originated in people’s colloquial speech, not from the company.

Levi’s jeans first appeared in *Vogue* in the 1930s. It was in this decade too when Eastern residents came back home from holidays in California wearing jeans, helping to popularize them on the East Coast. In 1934, Lady Levi’s, the first Levi’s for women, were created.

In the 1950s, the pants were adopted by rebels as a symbol of their nonconformism.

So closely were Levi’s associated with rebellious attitudes that in the 1950s, they were banned in schools throughout the country, but especially in the East. In the 1970s, jeans were already being worn by people from all social backgrounds. In the 1980s, the first designer jeans were produced, starting with those manufactured by Calvin Klein.

A fire following the San Francisco earthquake of 1906 destroyed the jeans company’s headquarters and two factories, forcing it to move. Levi’s had started as a family business in a small store in New York City, and it has continued to be a family-run company for the most part. In the 1970s, shares in Levi’s were first

sold in the stock market, but the company is still owned and under control by the descendants of Strauss's four nephews to whom he bequeathed his company. Levi's had 17,000 employees worldwide in 2016 (1,300 in its San Francisco headquarters), and it also produces the brands Dockers and Slates.

Despite the fierce competition in the jeans market, Levi's has managed to continue being strong in the very field it created. To help identify genuine Levi's, the two-horse logo began to be attached to the pants in 1886; in 1936, the red tab was added to the left rear pocket. Even in the face of cheaper competing products, Levi's has stayed in the business by appealing to those who want the genuine article. So precious are Levi's that there have been reported cases of the jeans being used in lieu of currency in wartime and during the Cuban embargo.

Associated with the American way of life and, therefore, with capitalism during the Cold War, jeans would not be introduced to the USSR until 1957, and they were mainly worn by students or tourists. In 1999 *Time* magazine chose Levi's jeans as "the Fashion Item of the Twentieth Century."

M. Carmen Gomez-Galisteo

Further Reading

Cray, Ed. 1978. *Levi's: The Shrink to Fit Business That Stretched to Cover the World*. Boston: Houghton Mifflin.

Jockstrap

Jockstraps are male undergarments designed to support and protect the penis and testicles during athletic activity. Although jockstraps can vary greatly in style, they typically consist of an elastic waistband with an attached support pouch into which a plastic or metal cup may be inserted for added protection.

Jockstraps were created by C. F. Bennett in 1874. Bennett worked for a sporting goods company and initially intended jockstraps for use by bicycle riders, then commonly referred to as "bike jockeys," a term that gave jockstraps their name. Jockstraps rose in popularity and were soon regarded as a standard garment for men playing contact sports such as wrestling, football, and basketball. Jockstraps became so

common that the term "jock" was coined to refer to males who play sports.

Although use of jockstraps in sports has dropped since the 1980s because of the invention of compression shorts, they continue to be strongly associated with athleticism and male fashion.

Alberta M. Miranda

See also Vibrator; *Vol. 1, Sec. 3: Hoop Skirt*

Further Reading

Kimmel, Michael S. 2014. *Cultural Encyclopedia of the Penis*. Landham, MD: Rowman & Littlefield.

Riess, Steven A. 2011. *Sports in America from Colonial Times to the Twenty-First Century*. Armonk, NY: M. E. Sharpe.

Jones, Amanda T. (1835–1914)

Inventor, writer, and entrepreneur Amanda Theodosia Jones innovated the use of oil as furnace fuel and founded an all-woman canning business based on her improvements in food preservation.

Jones was born in East Bloomfield, New York, and attended the East Aurora Academy. She graduated at 15 and began teaching. She taught for four years, all the while writing and publishing poems. She contracted tuberculosis in 1859 and spent a year recovering at her mother's house in Wisconsin. Shortly after, she published her first of six books. She also embraced spiritualism, a religious belief in spirit communication that was popular in the mid-19th century.

In 1869, she moved to Chicago and began experimenting with food preservation. She invented the Jones process to vacuum-pack fresh fruit. She first patented her process in 1872 and eventually applied for four more patents based on improvements in her process. In 1880, she invented an oil burner for furnaces. Capitalizing on the increasing availability of petroleum oil, she intended the oil burner to generate steam for powering glass manufacturing.

Jones founded the Women's Canning and Preserving Company in Chicago in 1890. Because she was an ardent supporter of women's rights and woman suffrage, she used her company to create meaningful paid labor for women. Her all-female company failed after

three years, however, after which Jones moved to Kansas to live with her sisters.

For the rest of her life, Jones continued to improve oil burners and canning processes. In 1904 and 1905, she published a series of four articles on the “liquid fuel problem” for an engineering journal. She also continued to write and publish poems. She published her autobiography in 1910. She died in 1914, a victim of influenza.

Peg A. Lamphier

See also Roebbing, Emily; *Vol. 2, Sec. 2: Bottle-Making Machine*; Bryant, Alice; Dickelman, Elizabeth; Petroleum Industry (Pre–World War II)

Further Reading

Shephard, Sue. 2006. *Pickled, Potted and Canned: How the Art and Science of Food Preserving Changed the World*. New York: Simon and Schuster.

Primary Document: “The Soldier’s Mother” by Amanda T. Jones (1867)

Americans in the 19th century did not subscribe to the more contemporary notion that the humanities and sciences were two entirely different fields of intellectual endeavor; thus, they did not believe that people who were “scientific” or technologically minded were unsuited or unable to also be poets, artists, or writers. Inventor and businesswoman Amanda T. Jones, founder of the all-female Women’s Canning and Preserving Company (1890) was also a songwriter and poet. The poem here suggests the Civil War’s profound influence.

The Soldier’s Mother

Awake, little daughter, awake!
The sad moon is weaving her shroud;
The pale, drooping lily-bells quake;
The river is sobbing aloud.
I wand your sweet face in my sight,
While I open my room to the night:
The torn clouds are flying, the lupine is sighing,
The whip-poor-will wails in affright.
There’s a shadow just marked on the floor—
Now soaring and breaking its bond;
’T is the woodbine, perhaps, by the door,
Or the blooming acacia beyond.
Oh, pitiful weakness of grief!
Oh, trouble, of troubles the chief!
When shades can assail us, and terrors impale us,

At sight of a quivering leaf.
I weep, little daughter, I weep;
But chide me not, love, for I heard,
Three times in the depth of my sleep,
The clang of a terrible word.

“Your Harry is dying,” it cried;
“Is dying” and “dying,” it sighed;
As bells that, in tolling, set echoes to rolling,
Till fainting sound ebbs like the tide.

Then the walls of my room fell away;
My eye pierced the distance afar,
Where, by the plowed field of the fray,
The camp-fire shone out like a star.
And southward, unhindered, I fled,
By the instinct of motherhood led;
The night-wind was blowing, the red blood was
flowing,
And Harry was dying—was dead!

I dreamed, little daughter, I dreamed—
Look! the window is lit by a face.
It is not? Well, how lifelike it seemed!
Go, draw down the curtains of lace.
It may be ’t was only a flower;
For fancy has wonderful power.
The loud wind is whirring—hark! something is stirring—
’T is midnight—the clock knells the hour.

The horseman had ridden all night;
His garments were spotted with gore;
His foot crushed the lily-bells white—
He entered the vine-covered door.
“Your Harry is dying,” he said:
The mother just lifted her head,
And answered, unweeping, like one who is
sleeping,
“Not dying, good soldier, but dead!”

Source: Jones, Amanda T. 1867. *Poems*. New York: Hurd and Houghton, 67–69.

Kellogg, William Keith (1860–1951)

William Keith (W. K.) Kellogg was a philanthropist, businessman, and founder of the Kellogg Company. He placed an indelible mark on industry and contributed to America's cereal craze. Born April 7, 1860, in Battle Creek, Michigan, Kellogg was the seventh of 16 children and the younger brother of John Kellogg, an eccentric physician and director of the Battle Creek Sanitarium. A member of the Seventh-day Adventist Church, Kellogg believed in the virtues of a healthy diet and worked to create a healthy breakfast alternative. He is best known for accidentally discovering the process for creating cornflakes. Because of Kellogg's ingenuity, the Kellogg Company has dominated the breakfast cereal industry since its founding in 1906, with its products manufactured in 18 countries and marketed across the globe.

Prior to the 1890s, the American breakfast consisted of porridge or gruel. To encourage better eating habits, sanitariums were created to serve as health facilities. The Battle Creek Sanitarium promoted the ideas of the Seventh-day Adventist sect and emphasized rest, exercise, and a vegetarian diet. Kellogg was hired as Battle Creek Sanitarium's accountant and manager of daily operations. He also worked to create a palatable meat substitute, which led to his famous discovery—cereal flakes. Kellogg stumbled on the flakes when he accidentally left wheat cooking on the kitchen stove. After the cooked wheat hardened, Kellogg wondered what could possibly be done to salvage what seemed to be a culinary disaster. He decided to roll out the hardened wheat and bake it. The result was wheat flakes.

Kellogg saw the potential profit to be made and believed it should not be sold exclusively to sanitarium guests. Unlike his brother, who welcomed visitors to witness firsthand the production of wheat flakes, Kellogg wanted to safeguard the trade secrets and objected to guests viewing the manufacturing process. His fears were realized when C. W. Post, a guest at the Battle Creek Sanitarium, created his own cereal after visiting the Battle Creek factory and became a competitor in the breakfast cereal industry. The success of Post angered Kellogg and widened the rift between him and his brother.

In 1898, Kellogg improved the flakes by using corn instead of wheat. The new and improved flakes were produced under the company name Battle Creek Toasted Corn Flake Company, founded in 1906 and renamed the Kellogg Company in 1925. Even though the company became a million-dollar success, tensions continued to grow between the two brothers, leading Kellogg to take the drastic step of creating his own company. He also gained exclusive rights to the Kellogg name. To distinguish his cornflakes from those of competitors, Kellogg placed his signature on each box and added the slogan "Beware of imitations. None genuine without this signature." Additional modifications were made to the ingredients to improve shelf life, and later, sugar was added to enhance the taste. Kellogg also utilized creative marketing methods that targeted children, such as gaining sponsorship from children's programming and including prizes with each box of cereal.

Kellogg used his great wealth to improve society and help those in need. His property in Michigan was donated to Michigan State University, and his horse ranch in Pomona, California, became the home of California State Polytechnic University at Pomona. In response to the Great Depression, Kellogg changed employee shifts from 40 to 30 hours per week; hence, he created four six-hour shifts. As a result, Kellogg hired more employees, which greatly helped the people of Battle Creek. In 1930, President Herbert Hoover made Kellogg a delegate to the White House Conference on Child Health and Protection. His experience inspired him to create the W. K. Kellogg Child Welfare Foundation with the objective of improving the health and education of children. Later, it was expanded and renamed the W. K. Kellogg Foundation, which is one of the richest organizations in the United States. Kellogg believed in helping those who were less fortunate and ensuring the success of future generations. To guarantee the foundation's longevity, Kellogg willed 60 percent of the company's interest to the foundation. Kellogg died October 6, 1951, due to heart failure.

Roshunda L. Belton

See also Food Preservation; *Vol. 2, Sec. 2*: Hoosier Cabinet; *Vol. 3, Sec. 1*: TV Dinner

Further Reading

Powell, Horace. 1956. *The Original Has This Signature—W. K. Kellogg*. Englewood Cliffs, NJ: Prentice-Hall.

Scott, Bruce, and Bill Crawford. 1995. *Cerealizing America: The Unsweetened Story of American Breakfast Cereal*. London: Faber & Faber.

Kelly, William (1811–1888)

American inventor William Kelly pioneered the Pneumatic Steelmaking Process. Harry Bessemer patented a similar process in 1855. A company purchased both patents and licensed them as Bessemer Steel. History remembers Bessemer, but Kelly's role in steel production innovation is relatively unknown.

Born in Pittsburgh, Pennsylvania, on August 21, 1811, Kelly studied metallurgy at Western University in Pennsylvania before beginning his career in the dry goods industry. At the age of 35, he became a senior partner in the Pittsburgh dry goods and shipping company McShane & Kelly. While traveling for the company, he gained an interest in the iron industry, which was in high demand due to a rapidly expanding cross-country railroad network and the development of mass production following the Industrial Revolution. He moved to Eddyville, Kentucky, where he purchased over 14,000 acres of timberland rich in carbon-free iron ore deposits. Alongside his brother and brother-in-law, he established Eddyville Iron Works using the property's deposits to supply ore for a steel forge while using the timber as charcoal fuel. As the timberland depleted due to the intense fuel demands of smelting the ore and forging the pig iron into steel, Kelly began searching for a means of improving ore refinement to save on charcoal costs.

At the time, iron was sold in three forms. Cast iron had a high carbon content, which made it strong but brittle. Wrought iron was cast iron heated in a low-oxygen environment to remove all carbon. Steel, the strongest variant, had intermediate carbon content and was produced by heating the iron slowly to high temperatures. This made the process expensive and therefore little used. There was no large-scale iron production, and all ironwork was produced by individual artisan foundrymasters in small batches.



William Kelly, shown here, coinvented the Bessemer process for the mass production of steel. William Kelly and Henry Bessemer independently discovered a method for injecting air into molten iron to transform it to steel. (Library of Congress)

In 1847, Kelly began experiments, first at Union Forge and then at Suwanee Furnace in 1851. He designed a cupola furnace with perforations underneath called “tuyeres.” Molten pig iron was poured into the cupola, and hot air was blasted through the tuyeres. The air blown into the iron caused the molten mass to become white hot, forcing impurities, including carbon, to the surface, where they vented as gases mixed with oxygen and burned to keep the iron molten. This process essentially turned the impurities in the iron into fuel without manually feeding the furnace. Kelly initially called his idea “air-boiling,” but the innovation came to be known as “Kelly’s pneumatic process.”

In 1856, Kelly discovered that Sir Henry Bessemer had patented a similar process in Britain and was trying for the American patent. Kelly managed to file a priority claim to the patent office and successfully superseded Bessemer’s claim. In 1863, the Kelly Pneumatic Process Company was organized, but Kelly

did not receive significant remuneration for his invention until the patent was extended in 1871. He retired to Louisville, Kentucky, where he died on February 11, 1888.

Andres Elvira

See also *Vol. 1, Sec. 1: Iron- and Silversmithing; Vol. 1, Sec. 3: Coal-Mining Technologies; Gold-Mining Technologies*

Further Reading

Knowles, Anne Kelly. 2013. *Mastering Iron: The Struggle to Modernize an American Industry, 1800–1868*. Chicago: University of Chicago Press.

Kobus, Ken. 2015. *City of Steel: How Pittsburgh Became the World's Steelmaking Capital During the Carnegie Era*. London: Rowman & Littlefield.

Kier, Samuel (1813–1874)

Inventor and businessman Samuel Kier developed the early American petroleum industry in the 1850s. He was the first to refine crude oil into usable lamp oil.

Although Samuel Kier moved to Pennsylvania at the age of 21, he was born in Saltsburg. His first business endeavor, which he undertook with James Buchanan, who would eventually become the 15th president of the United States, was in canal boats. Kier and Buchanan's company transported canal boats between Philadelphia and Pittsburgh.

In 1847, Samuel and his father, Thomas, went into the business of salt refining. Collecting salt from salt water had a major adverse side effect: oil would get into the salt wells and dirty the salt. Initially, this oil was dumped into the Pennsylvania canal. Kier then determined to do something with the waste oil, particularly after a group of Tarentum residents discovered its ability to produce light. They did so by throwing a burning branch into the stained canal, where, much to their surprise, the oil caught fire.

In 1848, Samuel's doctor prescribed "American Medicinal Oil" to his wife, who had been diagnosed with tuberculosis. The medicine struck Samuel as very familiar, and he eventually realized that it was strikingly similar to the oil that his salt refining company was dumping

into the Pennsylvania canal. Seeing that this was the case, by packaging the oil into small bottles and heavily marketing the product as a natural remedy, Samuel Kier was able to profit from the previously wasted oil.

Samuel Kier next began explore the other possibilities in oil. He went to professor James C. Booth, a chemist in the Pennsylvania region, who analyzed the sample and recommended that Kier distill the oil. Booth provided Kier with plans to build a small still for this. In collaboration with industrialist John T. Kirkpatrick, Kier built the still on Seventh Avenue in Pittsburgh. It consisted of a small kettle that could produce a barrel of distilled crude oil. After several failed attempts, Samuel was able to streamline his process and become more efficient. Eventually he produced an oil that could be used for lighting. He called the product "carbon oil."

In a time when it was difficult to find cheap and reliable sources of light, Kier's carbon oil changed the game. Kier invented a lamp that could resourcefully burn his carbon oil without producing an obnoxious amount of smoke. These lamps were the most efficient available, capable of producing a very bright light source, particularly compared to candles and whale oil lamps. Samuel Kier never bothered to patent his refining process, allowing others to make improvements to his procedures. This would eventually pave the way for the modern petroleum refining.

George Bissell saw opportunity in what Samuel Kier had accomplished and decided to form the Pennsylvania Rock Oil Company. Edwin Drake became the general manager behind James Townsend's business of providing oil to the company. With some help, Drake began drilling for oil in Titusville. He met up with the blacksmith who produced tools for Samuel Kier and continued his search for more sources of "rock oil." Eventually, Drake succeeded in his quest and was responsible for finding an oil source in Pennsylvania capable of filling nearly 3 million barrels. The petroleum refining business in America had begun.

Sebastian Gottwald

See also *Vol. 1, Sec. 3: Gas Well; Gold-Mining Technologies; Vol. 2, Sec. 2: Automobile Technologies (Pre-World War II); Ford, Henry; General Motors (GM)*

Further Reading

Leffler, William. 2008. *Petroleum Refining in Nontechnical Language*. Tulsa, OK: PennWell Corp.

Raymond, Martin. 2005. *Oil & Gas Production in Nontechnical Language*. Tulsa, OK: PennWell Corp.

Kinematoscope

A 19th-century machine that displayed a series of still photographs in rapid succession in chronological order, making the object in the photos appear to be moving, the Kinematoscope was different from other devices of the time because it was not a projector; one person at a time viewed the photographs, and the photos displayed were stereoscopic.

Coleman Sellers II (1827–1907) was an engineer and the inventor of the Kinematoscope. He held several patents. His inventions were known for their simplicity and efficiency.

Illustrated engineering books of the time did not clearly depict how machines worked. Magazine advertisements for machinery were not clear either. The drawings of moving parts were confusing. Sellers studied photography to find a way to show precisely how machine components moved.

The Kinematoscope required a series of stereoscopic photographs. A stereoscopic image is created when two photographs are taken of the same object from slightly different angles. When the two offset two-dimensional photos are shown together, the individual viewing the images perceives the illusion of depth.

The illusion of movement was created based on the principle of persistence of vision. It refers to the rapid viewing of multiple still images, resulting in the images blending together to give the illusion of motion.

The first photograph in the series displayed in the Kinematoscope showed the object at rest. The object would be moved slightly, and another photo was taken. The object was moved slightly again and another photo taken. This continued until the cycle of motion was complete. When the series of photographs was displayed in the Kinematoscope, the object would

appear to have depth and to be moving. Subjects of these photo series included a machine wheel turning and a boy hammering a nail.

The Kinematoscope consisted of a cabinet that held an eyepiece to view the photographs, a shield to keep light out of the eyepiece, stereoscopic prisms to get the stereoscopic effect, and a rotating cylinder case that held the photographs. Stereoscopic prints were attached to the cylinder horizontally. Turning the cylinder rotated the photos in “rolodex,” or rolling index-style, presentation before the viewing lenses. The eyepiece and shield were on the top of the cabinet; a knob to turn the cylinder of photos was on the side. The prisms and cylinder of photos were inside the cabinet.

Sellers titled his patent application “Exhibiting Stereoscopic Pictures of Moving Objects” and received the patent in 1861. He advanced the study of pictures of motion and photography a step closer to the motion picture technology developed later that century.

Linda Briley-Webb

See also Edison, Thomas

Further Reading

Coleman Sellers II, assignee. 1861. Viewing or Reading Apparatus for Moving Picture Effect. U.S. Patent 31,357, issued February 5, 1861.

“Exhibiting Stereoscopic Pictures of Moving Objects.” 1903. *Cassier’s Magazine Engineering Illustrated* XXIV (October): 352–62.

“In Memoriam Coleman Sellers.” 1908. *Journal of the Franklin Institute* 165, no. 3 (March): 165–72.

Morton, Henry. “Coleman Sellers, E.D., Sc.D. A Biographical Sketch.” *Cassier’s Magazine: An Engineering Monthly*. New York, Vol. 24, p. 352.

Knight, Margaret (1838–1914)

American inventor Margaret Knight was known as the “Lady Edison” for conceiving and improving more than 50 inventions and receiving about 27 patents on some of them. One of the inventions she is most known for is a machine for creating flat-bottomed grocery bags. The flat-bottomed paper bag has been in continuous use since its creation in 1868.

In 1838, Knight was born in York, Maine, to her parents James Knight and Hannah Teal. At the age of 12, her father died. At the same age, she aided her family by working at a textile mill. While there, she witnessed a worker injured by a steel-tipped object released from a mechanical loom shuttle. From this observation, Knight had the idea for a way to prevent this type of accident, creating a cover for the shuttle while it is in use. Her new invention was successful, stopping a projectile from shooting out of the shuttle. But because she was only 12 years old, Knight lacked knowledge of patents, so her invention, widely used in other mills, never resulted in profit.

By 1868, Knight went to Springfield, Massachusetts, to work at the Columbia Paper Bag Company. During this time, bags used at stores were flat, with an envelope opening. While working at this factory, Knight had the idea to create a bag that would be more useful. The new bag would have a flat bottom instead of being flat throughout. Such a flat bottom also benefited companies that wished to advertise the products in the bags since the bags could stand up.

For Knight's new invention to be widely produced, a machine was needed that could both fold and glue the bottoms of the bags. After experimenting with and altering the machine that she used at work, Knight created an iron machine that created flat-bottomed bags consistently. She took her invention to Boston, where she could improve upon it and patent her idea. During this time, another inventor, Charles F. Annan, stole her idea and attempted to patent it. Knight witnessed this and contested Annan in court. In 1871, Knight won the lawsuit; thus, her new invention was patented under her name. Later, she opened her Eastern Paper Bag Company in Massachusetts.

Knight's invention of the flat-bottomed paper bag has survived since the 19th century and is still in use at many stores. This was not Knight's only patented invention. She had many other patents, including ones for lid-removing pliers, a shoe-cutting machine, and a dress and skirt shield; thus, she was nicknamed "Lady Edison." Knight died at the age of 76 on October 12, 1914, due to pneumonia.

Alan S. Peña

See also *Vol. 1, Sec. 1:* Loom; *Vol. 1, Sec. 2:* Lowell Mill System; *Vol. 2, Sec. 3:* Plastic Wrap; *Vol. 3, Sec. 1:* Plastics

Further Reading

Kulling, Monica, and David Parkins. 2013. *In the Bag!: Margaret Knight Wraps It Up*. Northampton, MA: Tundra.

"Margaret Knight." ASME. <https://www.asme.org/engineering-topics/articles/diversity/margaret-knight>, accessed August 29, 2018.

Thimmes, Catherine, and Melissa Sweet. 2002. *Girls Think of Everything: Stories of Ingenious Inventions by Women*. Boston: Houghton Mifflin.

Lady Stitchers' Union

The Lady Stitchers' Union formed in Lynn, Massachusetts, in 1883 to protest working conditions and wages, and by 1886, it had organized almost 3,000 women, representing over two-thirds of the female workforce in the area. Recognized as an assembly by the national Knights of Labor, this union was also known as the Daughters of Labor. Just as the men of the Journeymen Cordwainers' Society had refused to admit women as members, the Lady Stitchers' Union restricted membership to women who worked as shoe stitchers instead of seeking a broad base of women engaged in all trades. As a body, the Lady Stitchers' Union could provide representation for workers to the state board of arbitration, which was responsible for settling disagreements between workers and factory owners.

With the dissolution of the Knights of Labor, many stitchers were later recruited into a new organization that emerged in the 1890s, the Boot and Shoe Workers Union. Thus, women in the Lady Stitchers' Union both stood up for their rights as workers and resisted the gendered double standard of many labor unions at a time when American society had difficulty recognizing women as waged laborers.

Rebecca Kohn

See also *Vol. 1, Sec. 2:* Canning Factory; *Vol. 1, Sec. 3:* Sewing Machine, Automated

Further Reading

Blewett, Mary H. 1988. *Men, Women, and Work: Class, Gender, and Protest in the New England Shoe Industry, 1780–1910*. Urbana: University of Illinois Press.

Lawn Mower, Reel-Type

A reel-type lawn mower has blades that spin north to south in a scissoring action. This type of mower, often called a “push mower,” usually has three to seven rotating blades. Amariah Hills of Hockanum, Connecticut, received the patent for the reel-type lawn mower in 1868.

Hills was the first person in the United States to receive the patent, even though in 1830, inventor Edwin Beard Budding, an engineer from Gloucestershire, England, had also designed a reel-type lawn mower. His mower worked by rotating a blade around the horizontal axis of the cylindrical shape of the mower; it was also known as the cylinder mower. It used two large cast-iron rollers that gave the traction needed to rotate the blades between the rollers. When Hills applied for the first American patent for the reel-type lawn mower, he opened up the cylinder housing. He also improved on it by allowing for height adjustment and improving how the handle attached to the mower’s frame. His mower was human powered, lightweight, and easy to use.

Amariah Hills began his designs for the reel-type lawn mower in 1861 and began manufacturing the machine in 1867 at the Curtis silver plate factory in Glastonbury, Connecticut. Hills sold the patents to Caleb Talcott, who created the company Archimedean Lawn Mower Co. in 1871. The name “Archimedean” came from how the reel-type lawn mower’s spiral cutter looked like an Archimedean screw. The lawn mower was widely accepted, and the “Charter Oak” model had an advertisement that called it “the most beautiful and perfect lawn mower in the world.” The reel mower does not cut very tall grass that well, but once a patch of grass is cut to a lower height, it can easily manage the height of the grass as well as keep the lawn healthy. Indeed, lawn enthusiasts contend

that the reel-type mower creates healthier lawn and creates a more professional, manicured look.

Joshua Drewry

See also Vol. 1, Sec. 3: Rotary Hook (for Sewing Machines); Vol. 3, Sec. 2: Sustainable Agriculture

Further Reading

Brown, Jonathan. 1994. *Farm Tools and Techniques: An Illustrated History*. London: B. T. Batsford.

Cobleigh, Rolfe. 2005. *Old-Time Farm and Garden Devices and How to Make Them*. New York: Dover.

Lennox, David (1855–1947)

David Lennox was an American mechanic, inventor, and businessman and the first to manufacture the riveted steel sheet metal coal furnace. He demonstrated his business skills with the creation of the Lennox Machine Company in 1895, which has evolved to an intercontinental company now known as Lennox International Inc.

Lennox was born in Detroit, Michigan, on April 15, 1855, the first of four children to Martin and Ellen Lennox. In the late 1850s, the family decided to move to Aurora, Illinois. Lennox’s father volunteered in the Civil War and was killed on May 16, 1863. This event greatly affected the family. Lennox was separated from his mother and sent to the Soldiers’ Orphans Home in Springfield, Illinois. Later, he rejoined his family and attended Bryant and Stratton Business College.

Like his father, Lennox was an expert railroad mechanic who quickly became interested in the use of tools and machines. After struggling to support himself financially, he decided to open his own machine shop. His first invention was a staple-cutting machine. The invention was an instant success, and the reputation for his Lennox Machine Shop grew quickly.

One day, a couple by the names of Ernest Bryant and Ezra Smith showed Lennox their plans for a new furnace. The furnace they described used riveted steel instead of cast iron. The quality and safety advantages of such a furnace were enormous. Cast-iron furnaces

were prone to warping over time, leading to cracks and allowing smoke and coal gas to leak into the home. Lennox and the couple solved this problem, and after making a number of modifications to the original design, began the construction of the new furnace, which became such a great success that in 1903 alone, over 1,500 furnaces were produced.

In 1904, Lennox decided to sell his business, the Lennox Furnace Company, to a local group led by D. W. Norris. Lennox continued to manage the company, which employed over 100 people at the time. Today, it is a multinational corporation called Lennox Industries, specializing in climate control products for heating, ventilation, air-conditioning, and refrigeration. The company is traded on the New York Stock Exchange and has a current market cap of over \$6.5 billion.

On February 15, 1947, Lennox died at the age of 91. His revolutionary work, which began with his job as a railroad mechanic and led to creating his own company that manufactured a revolutionary furnace, shows how bright ideas can change the world.

Emma E. L. Burke

See also *Vol. 1, Sec. 3: Coal-Mining Technologies*

Further Reading

Battin, W., and F. A. Moscrip. 2001. *Past and Present of Marshall County, Iowa*. La Crosse, WI: Brookhaven Press.

Voght, Michael W. 2009. "Lennox, David." *The Biographical Dictionary of Iowa*. Iowa City: University of Iowa Press.

Linotype Machine

The Linotype machine was invented by Ottmar Mergenthaler (1854–1899) in 1883 and revolutionized printing. This "line casting" machine produced an entire line of type in a single piece of lead called a "slug." The machine revolutionized the letterpress printing industry by speeding up the process of typesetting, which previously had required compositors to set individual letters by hand.

Mergenthaler was born in Württemberg, Germany, on May 11, 1854. He trained as a watchmaker's



Linotype machines use a hot metal typesetting system to cast lines of type, rather than typesetting letter by letter. These machines revolutionized printing, particularly in the newspaper business. (Library of Congress)

apprentice and in 1872 immigrated to the United States, where he worked building scientific instruments for his step-cousin August Hahl in Washington, D.C. When Hahl moved his shop to Baltimore, Mergenthaler relocated and eventually became his business partner.

In 1876, Mergenthaler was asked to troubleshoot Charles T. Moore's patented design for a newspaper typewriter that would replace the need to hand-set type. Mergenthaler dedicated himself to working out the mechanics of the system, but after two years of this, it became apparent that the design was flawed.

Undeterred, Mergenthaler designed his own machine that could cast lead type and do typesetting in one operation. He produced an experimental model and in 1883 built a full-size working machine. Like other typesetting machines in use during the 1880s, this one punched letters into a papier-mâché matrix, which was then used to cast type.

Mergenthaler tried a new approach that would do away with the intermediate papier-mâché matrix so that the matrices could be stamped directly onto the metal and cast into type. In 1884, he demonstrated the direct casting band machine to a group of financial backers, and together they formed the National Typographic Company. Justifying (aligning) type was a problem, but Mergenthaler added a space band that would insert space at intervals along the line of type and produce even margins.

In 1885, Mergenthaler formed the Mergenthaler Printing Company and built 12 machines, initially called “blowers” and later named Linotype for the “line of type” they produced. The first machine was sold to the *New York Tribune*, and on July 3, 1886, the first newspaper composed on a Linotype machine went to press.

Trouble with his financial backers led to Mergenthaler’s resignation in 1888, so he launched Ottmar Mergenthaler & Company in Baltimore, where he manufactured parts for Linotype machines. In 1891, both companies merged into Mergenthaler Linotype Company. Within a few years, Mergenthaler fell ill with tuberculosis. In 1894, he moved to New Mexico for recuperation, but his health worsened and he died in 1899.

The patents on the Linotype machine expired in 1911, and competitors such as Intertype quickly entered the profitable market. The Mergenthaler Linotype Company published *The Linotype Bulletin* and mailed it to printers at no cost. The *Bulletin* ran news articles, contests, and help-wanted listings in addition to showcasing the company’s fonts and decorative type elements.

In the mid-1950s, more than 70,000 Linotype machines were in use, but by 1975, hot metal typesetting gave way to phototypesetting systems such as the Linotype CRTronic, until these were edged out by desktop publishing systems in the 1990s.

Karen S. Garvin

See also Vol. 1, Sec. 3: Papermaking Machine; Printing

Further Reading

Kahan, Basil. 1992. *Ottmar Mergenthaler: The Man and His Machine*. New Castle, DE: Oak Knoll Books.

Romano, Frank. 2014. *History of the Linotype Company*. Rochester, NY: RIT Press.

Margarine

New Yorker Henry Bradley patented a vegetable-based margarine, sometimes called “oleo” or “oleo-margarine,” in 1871. By the beginning of the 20th century, over three dozen American companies were manufacturing the butter substitute. In the mid-20th century, Americans ate more margarine than butter, in part because it was cheaper and in part because manufacturers claimed it was more healthful. Such claims have since been debunked.

While faux butter, or margarine, dates back to the early 1800s, the spread was once made with beef fat. Henry Bradley developed a process that combined cottonseed oil with other vegetable oils and emulsified them into a butter-like spread. The spread became so popular that the butter industry fought back. In 1886, the U.S. Congress passed the Margarine Act that taxed margarine at five times the rate of butter. The act was repealed in 1850.

While margarine is less popular in the early 21st century, it remains a viable commercial product. Observant Jews use margarine as a dairy substitute, as do vegans and the lactose intolerant. Oleo or margarine is often referred to as “nondairy spread.”

Peg A. Lamphier

See also Vol. 2, Sec. 3: M&M’s; Vol. 3, Sec. 1: TV Dinner; Vol. 3, Sec. 2: Sustainable Agriculture

Further Reading

Offit, Paul. 2017. *Pandora’s Lab: Seven Stories of Science Gone Wrong*. Washington, D.C.: National Geographic.

Matchbook Matches

A matchbook cover is a small, thin, cardboard paper that covers a pack or strip of matches that is made to be opened and closed like a cover of a book. A person rips a stick out of the book and strikes it once along a black strip to cause the stick to light up with fire. The cover of the matchbook may contain an advertisement, a logo, or artwork.

In 1826, John Walker noticed that a stick that was coated in sulfur accidentally burst into flame when he scraped it on the bottom of his fireplace. Coincidentally, Walker was a chemist, so, with his curiosity, he was the first to invent a friction match. In 1889, this led an attorney named Joshua Pusey to be interested in inventing and holding a patent for the matchbook. After 1894, it grew in popularity. American companies started to add advertisements to matchbooks. They were popular during this time because they were small, portable, easy to use, affordable, safe, and allowed a person to light one small stick at a time.

Matchbook matches still exist and are readily available. One can find them in places like hotels, restaurants, and gas stations. Matchbook matches can be custom made for weddings and other special events.

Pamela Solis

See also Folding Cabinet Bed; Paper Clip; Spork

Further Reading

Daniels, Samantha. 2005. *Matchbook: The Diary of a Modern-Day Matchmaker*. New York: Simon & Schuster.

Matzeliger, Jan Ernst (1852–1889)

Jan Ernst Matzeliger was an inventor who devoted his life to the design, patent, and manufacture of the first shoe lasting machine. The machine completely revolutionized the shoe industry, increasing the manufacturing output capacity of shoes by more than 10 times and making shoes more affordable even for the average person.

Matzeliger was born on September 15, 1852, in Paramaribo, Republic of Suriname. His father was a

Dutch engineer, and his mother was Surinamese. When he was 10 years old, Matzeliger worked in machine shops that his father supervised. When he was 19, he left his family and decided to travel the world, and in 1873, he settled in Philadelphia. Because of his dark skin, Matzeliger struggled to find a sustainable job and decided to resettle in Massachusetts and seek work in the shoe industry.

At the time, the shoe industry was still in its infancy. Cobblers made each shoe almost entirely by hand, through a very delicate and tedious process. Molds of customers' feet had to be made with wood or stone, from which the shoes were sized and shaped. Attaching the body of the shoe to its sole was done entirely by hand. Matzeliger realized that there was a need for improvement and set out to find a solution. He knew that to increase output capacity, much of the manufacturing process had to be automated by machines.

Matzeliger came up with many designs, and after years of development, he applied for a patent on a "lasting machine." On March 20, 1883, Matzeliger received patent number 274,207 for his machine. His machine produced from 150 to 700 pairs of shoes per day, compared to the 50 pairs of a typical skilled worker. Because of the overwhelming demand for the machine, the Consolidated Lasting Machine Company was formed, which began producing shoes in massive quantities.

Unfortunately, Matzeliger did not see the full success of his invention, dying on August 24, 1889, at the age of 36. His early death had been caused by a quickly developing tuberculosis as he spent countless hours working on his inventions, not eating for long periods. Yet, even after his death, his work continued to disrupt the shoe industry. A merger of the Consolidated Lasting Machine Company and a few others led to the creation of a new company called the United Shoe Machinery Company. USMC continued to revolutionize shoe manufacturing and the shoe industry itself. With over 800 new and improved shoe machines and more than 9,000 patented inventions, the USMC became one of the first three international companies ever formed to become a worldwide powerhouse.

Emma E. L. Burke

See also Amalgamated Clothing Workers of America (ACWA); *Vol. 3, Sec. 1: “Air” Athletic Shoes*

Further Reading

Matzeliger, J. E. 1883. Lasting Machine with One Lasting Gripper. U.S. Patent 274,207, issued March 20, 1883.

Mitchell, B., and H. Mitchell. 1986. *Shoes for Everyone: A Story about Jan Matzeliger*. Minneapolis: Carolrhoda Books.

Maxim, Hudson (1853–1927)

Hudson Maxim was an American chemist who invented several different explosives, including smokeless gunpowder, a propellant used in firearms and artillery that produces small amounts of smoke when fired. The original form of gunpowder, called black powder, produced a significant amount of smoke. In his risky experimental career, he lost his left hand in a mercury fulminate explosion in 1912. During World War I, Maxim wrote a book titled *Defenseless America*, in which he pointed out the American defense system’s weakness against foreign aggressors and the vulnerability of the country to attacks.

In the mid-1800s, gun technology and warfare were changing. Smokeless gunpowder transformed the efficiency and methods used in firearms. Maxim is comparable to Steve Jobs in today’s day and age with his innovative thoughts and remarkable ability to bring to life what no one knew they needed.

Black powder had been the world’s choice of explosive and gun propellant for thousands of years. It was made by mixing sulfur, charcoal, and potassium nitrate, which was often mined on distant islands with large bird populations, or from caves populated by bats; their droppings were rich in the needed ingredients. Very few changes were made to black powder’s mixture until the strain of the wars, and the thirst for ingenuity began.

Black powder was an unreliable resource and had several problems in battle. Its use would quickly block the battlefield with thick smoke, making it difficult for soldiers to see. One of the main issues was that if the powder became wet, it would not burn, leaving

soldiers defenseless. Without smokeless gun powder, military snipers would give up their positions before even taking a shot, making all following shots dangerous. And, when the trigger was pulled, smoke would surround the gun from the time the shot left the barrel. Not only was this not ideal for battle, it wasn’t hunter friendly either. The time delay allowed animals to disappear before the next shot.

Guncotton was the main ingredient in smokeless powder. The mixture created something with more than triple the amount of power than regular gunpowder, and it burned with little to no smoke. Without Hudson Maxim’s invention of smokeless powder, there would have been a massive innovation gap between the eras. Maxim was a pioneer of his time and contributed greatly to the success of this nation.

Peg A. Lamphier

See also *Vol. 1, Sec. 3: Dahlgren Gun; Interchangeable Gun Parts; Machine/Gatling Gun*

Further Reading

“Hudson Maxim Collection of Graphic Materials, Part I, 1890–1925.” 2014. Lemelson Center for the Study of Invention and Innovation. <http://invention.si.edu/hudson-maxim-collection-graphic-materials-part-i-1890-1925>, accessed August 29, 2018.

“Hudson Maxim Defends His Discovery of Smokeless Powder; The Noted Inventor Says That His Patents Bear a Date Previous to That Claimed by His Brother.” 1914. *New York Times*, November 8. <http://query.nytimes.com/gst/abstract.html?res=990CEED6133DE333A2575BC0A9679D946596D6CF&legacy=true>, accessed August 29, 2018.

Metal Detector

The metal detector was first invented by Alexander Graham Bell during one of the most disastrous moments in U.S. history. This invention was possible because Bell had already invented the telephone several years earlier, and some of the concepts, ideas, and knowledge were transferred to the first metal detector. Bell invented it to detect the bullets inside

President James A. Garfield's body after he was shot in an assassination. Although it failed to save the president, the idea of detecting the existence of metal was passed on to many other applications. Today, metal detectors can be found in every industry from amateur treasure hunting to security systems in all industries.

The idea behind the first metal detector is simple. Any magnetic field is disrupted when there is a metallic object inside the field. If there is a way to capture that moment of disruption, the approximate location of the object can be pinpointed by reducing the area or strength of the magnetic field. This is achieved by using an electrically induced magnetic field that can be adjusted by adding or removing the number of coils. The easiest way to capture the moment is to use telephone technology, which captures sounds from electric current. By combining a telephone receiver and electrically induced magnet, the first metal detector was invented.

One major requirement for the first metal detector to work was that there could be no unnecessary metallic object near the target, because it would interfere with the magnetic field and create false positives. Most important, there should be no large metallic sheets in the background, which was the main reason that the detector might fail.

After a few adjustments, Bell's invention managed to detect the bullets in the clenched hand, pinpoint a bullet lodged in the back of an old veteran, and find a fresh bullet shot into some meat he had bought at butcher shop. However, the detector failed to pinpoint the bullet inside the president's body several times. One possibility was that the springs of the mattress he was on were made of metal. Due to skeptical doctors and the president's weak condition, Bell was barred from performing another test, and unfortunately, the president passed away from the bullet wound.

While the first metal detector failed to save the life of President Garfield, its improved version, a telephone probe, saved many lives in many wars, including World War I, before x-ray detectors were widely used. However, the role of metal detectors has not diminished. Modern metal detectors are more advanced and widely used in clearing land mines, searching for lost or

antique valuables, and for security purposes at airports and other large gathering events.

Wai L. Phyoo

See also Bell, Alexander Graham

Further Reading

Bernzweig, Daniel. 2014. "The History of the Metal Detector." Metaldetector.com.

Garrett, Charles L. 1985. *The Advanced Handbook on Modern Metal Detectors*. Dallas: Ram

Grosvenor, Edwin S., and Morgan Wesson. 1997. *Alexander Graham Bell: The Life and Times of the Man Who Invented the Telephone*. New York: Harry Abrams.

Metal Electrode Weld

The metal electrode was suggested by Charles Coffin as a filler to maintain the original structure of metals during the process of shielded arc welding, itself a welding technique patented by Coffin in 1889. Coffin's invention rectified the vulnerability of forge welding, which destroys the original shape of the metals. Soon after it was invented, shield arc welding played a big role in both World Wars in terms of shipbuilding.

Welding is a technology that was discovered independently and repeatedly by several communities throughout history. Before arc welding, forge welding was the main industrial practice. In forge welding, two pieces of metal are held together and heated to soften them so they can be merged by various methods, mainly hammering. Forge welding destroys the original metals, while shielded arc welding does not. It uses the electric arc invented by Sir Humphrey Davy of England in 1801. The electric arc is created by placing together two terminals of a high-voltage circuit, producing a bright light and emitting huge amounts of heat. Coffin used three pieces of metal to perform arc welding, placing all three of their edges and heating them with the arc. Two metals were joined by filling the gap with melted metal from a rod—the electrode core with carbon in it. It melts and becomes the filler metal.

Just as welding was discovered separately by different communities, arc welding was also discovered by another person around the same time. Nicholas G. Slavianoff invented similar shielded arc welding in England, applying for a patent on the “Electrical Casting of Metals.” However, his process was very similar to Coffin’s; the only difference was in the type of electrode. Slavianoff used bare metal while others used carbon electrodes.

The first American arc welding machine was imported from Germany in 1907. It had a 200-amp, 60-volt generator. By 1912, four companies offered arc welding machines in the United States, which proved useful during World War I. When the United States entered the war, it had a problem shipping supplies and manpower across the Atlantic Ocean and needed to build new ships quickly. Britain was using arc welding after the gas supply for gas welding ran out, so the States decided to use it build their new ships. Since then, arc welding has become a standard for building U.S. ships and was responsible for most of the ships built for World War II as well.

Today, arc welding is used around the world, and countless innovations were made to the original technique invented separately by Coffin and Slavianoff.

Wai L. Phyto

See also Vol. 2, Sec. 2: Welding, Alternating Current; Vol. 3, Sec. 1: CO₂ Welding

Further Reading

- Ballis, William L. 2011. *Shielded Metal Arc Welding*. n.p.: Xulon Press.
- Galvery, William L. 2007. *Welding Essentials*. New York: Industrial Press.
- McKetta, John J., Jr. 1976. *Encyclopedia of Chemical Processing and Design*. 66th ed. Vol. 67. New York: M. Dekker.

Metal Windmill

The first metal windmill, the “iron turbine,” was patented by J. S. Risdon in 1872 after being manufactured by the firm of Mast, Foos and Company at Springfield, Ohio. This was the first time that

windmills were made purely of metal, and the slow transition from wooden to metal windmills began. However, this took such a long time that wooden windmills were still used 60 years later in 1940.

Before World War I, wooden windmills were more popular than metal ones. When the British first settled in North America, they brought their windmill technology with them. During the colonial era, windmills were mainly used to grind grain. After the American Revolutionary War and various expansion westward, the purpose of windmills changed. By the 1870s, they were used mainly to pump water. However, they were still made of wood. The only metal parts were the screws and bolts.

After being patented in 1872, the iron turbine entered the market in 1876. Risdon claimed that it was the most powerful windmill at the time when compared to others of the same diameter. He had replaced straight blades with buckets on the solid wheel of the mill. There was another metal windmill that entered the market at the same time: the Leffel Iron Wind Engine. However, it was not completely made with metal; only its wheel and head were. The rest was still composed of wood. Metal windmill production increased in the United States starting from the 1890s, with the help of cheap steel prices.

In the 1880s, another notable metal windmill appeared. The Iron Duke entered the market with the slogan that it would not warp, shrink, swell, split, or decay, and its slats would not blow away in any storm. However, users were skeptical of metal windmills mainly because they were harder to repair. Farmers knew how to fix wooden windmills with nails and bolts. Hence, they were unwilling to switch over to the new windmills. Another reason that they wanted to continue using wooden windmills was because metal ones were weaker. Because of the weight of metal, they required more wind power to operate at the same level as wooden windmills. Manufacturers of metal windmills switched to lighter metal to quell the complaints. In fact, the metals they now used were lighter than necessary. Among customers, those from the Southwest region of the United States were the last to switch to metal windmills, believing that wooden lasted longer than their metal counterparts.



This 1880 engraving of the iron turbine wind engine, the first metal windmill, suggests the apparatus's importance to Western farming. Technically wind pumps, these machines pumped water to the surface, supplying crop irrigation and water for cattle. (Archive Photos/Getty Images)

Windmill technology has evolved by leaps and bounds since the 1900s, with countless innovations in design by numerous inventors around the world. Nowadays, windmills' purpose has changed again; they are mainly associated with generating environmentally friendly energy. Although the metal windmills invented by Risdon and others are no longer widely used, the current version of windmills might never have been possible without those durable metal windmills.

Wai L. Phyo

See also Vol. 3, Sec. 2: Solar Energy; Wind Energy

Further Reading

Baker, T. 1985. *A Field Guide to American Windmills*. Norman: University of Oklahoma Press.

Torrey, Volta. 1976. *Wind-Catchers: American Windmills of Yesterday and Tomorrow*. Brattleboro, VT: S. Greene Press.

Military Technology (Post-Civil War through World War I)

Military technology has constantly changed as wars have been fought. Improvements in technology and new ideas are aggressively pushed by every side at war to try to get the upper hand in battle. While military technology might arise around an immediate opportunity for advantage in battle, it can sometimes evolve into something that can help (or maybe hinder) civilian society. Most technology developed for military use consists of weapons, though some does not

necessarily have military application. Some technologies that were created and improved on through the Civil War and World War I still impact our lives today.

The Civil War helped create and improve technologies that would forever change how wars were fought. Civil War technology would not only have a drastic effect on the war's outcome but would also change future military strategy. Inventions and improvements during the Civil War included the rifle, repeaters, submarines, the railroad, and the telegraph.

Prior to the Civil War, soldiers had fought mainly with muskets, which only carried a single shot and took a long time to reload. The range of typical muskets was about 250 yards; they were much more effective and accurate at a closer range, which meant that armies usually had to approach each other relatively closely. While some rifles used in wars had a much better range, they were not as effective, because bullets were roughly the same size as rifle barrels and had to be hammered in with mallets. This changed in 1848, when a French Army officer named Claude Minié invented a cone-shaped lead bullet that would later be known as a “minié ball.” These bullets could be loaded much more quickly and had a farther firing distance. They also caused much more damaging wounds, which medical care at the time was ill prepared to handle. Wars would no longer be fought in close quarters, and even the soldiers in the distance had to find a means of protecting themselves. They did so by building forts or trenches.

The minié bullets allowed for easier reloading of rifles, but they still could only load one bullet at a time. This led to the creation of “repeater” rifles or weapons. The most famous repeater of the Civil War was the Spencer carbine. It was a much shorter and lighter version of the standard-issue muzzle-loading rifled musket. It was capable of shooting up to seven rounds in 30 seconds before having to be reloaded. The Henry rifle was another repeater that was introduced just before the start of the Civil War. Unlike the Spencer carbine, the Henry rifle had much less energy but could hold 16 rounds.

While the battles of the Civil War were mostly fought on land, there were important innovations that would change how wars would be fought on water and in the air. The Civil War saw a more aggressive

implementation of the use of submarines and balloons during warfare. Submarines had existed long before the Civil War, but it was the Confederate CSS *Hunley* that would go down in history as the first submarine to engage and sink an enemy vessel. The *Hunley* submarine was a 40-foot-long, 4-foot-wide metal tube operated by only an eight-man crew. The Union had a blockade that covered 3,500 miles of the Atlantic and Gulf Coast line that was preventing the Confederacy from trading and getting supplies to its soldiers. The coasts were guarded by the Union with the use of ironclad ships. Ironclad and steel armor-plated ships were implemented during the Civil War instead of wooden ships, which were vulnerable to explosions and incendiary fire. The Confederacy retaliated with the sinking of the *Housatonic*, which was one of the Union's blockade ships off the coast of Charleston. While the *Hunley* successfully sank an enemy vessel, it sank itself in the process.

While there is also evidence of balloons being used in battle as early as 1794, during the Civil War, they were used to spy on the enemy and to send information back to base via telegraph. One improvement to accomplish this was created by Union Chief Aeronaut Thaddeus Lowe: mobile hydrogen gas generators. They allowed soldiers to fill up balloons almost anywhere they needed to. This tactic by Union soldiers caused Confederate soldiers to come up with ways of disguising their troop numbers and movements by devising camouflage and the first campfire “blackouts.” These tactics would also be used later on in the World Wars.

While advancements in weapons changed the outcomes and tactics of battles, innovations like the railroad and the telegraph would cause much more impactful change to the entire world. The railroads had a massive impact on the outcome of the war by helping move large quantities of soldiers and supplies. Much like in all of the other technological advances during the Civil War, the Union had an advantage in obtaining and using them due to the majority of factories being in the North. Railroads in the North consisted of standard-gauge tracks that allowed trains to run on any of them, while in the South, there was no standard for tracks and thus, people had to switch trains constantly—which was highly inefficient.

The invention of the telegraph was another technology that gave the Union a major advantage over the Confederacy. With the telegraph, the Union was able to send and receive messages from the battlefield in real time, allowing them to adjust and strategize in a timely manner. This led to the establishment of the U.S. Military Telegraph Corps by the Union Army. Just a year after it was established in 1861, the Corps had run 4,000 miles of telegraph wire and trained 1,300 operators. Innovations like the railroad and telegraph are examples of military technologies that have evolved into other forms that still have an impact on us today.

World War I, like the Civil War, was the impetus for many technological advances that were initially implemented for war but would have an impact on civilian life as well. Some of the more impactful innovations to come from World War I are technologies like machine guns, tanks, and mobile x-ray machines.

As in the Civil War, the need for more rapid firepower was the focus during World War I. This resulted in the development of machine guns. The first machine guns were very primitive. Heavy and not suited for advancing armies, they were mostly used in groups to hold on to a defensive position. Even though they would regularly overheat or jam, the firepower they produced was like nothing ever seen before.

With just one machine gun capable of mowing down dozens of soldiers in a short time, armies had to come up with methods of protecting themselves from the line of fire. The creation of the automobile in the 1900s helped create a great military technology. Begin with a vehicle powered by a small combustion engine and heavily armor plated to take on enemy fire, add some firepower and replace the wheels with armored tread, and you have a tank. Tanks were initially very primitive as well, but they were much more efficient before the end of the war.

Sadly, the use of machine guns and tanks as well as other weapons caused soldiers to suffer gruesome wounds. This created a need to improve medical technology in the field as well. Prior to the Great War, x-ray machines were very large and too bulky to have out on the battlefield. Marie Curie helped create mobile x-ray stations for the French military soon after the war broke out. The machines were installed

in small trucks or cars that were accompanied with smaller surgical stations at the front. Before the end of the war, there were 18 “radiologic cars” or, as some called them, “little Curies” in operation.

War is the cause of great death and destruction, but ironically, it has also been the cause of many great, innovative technologies. Through the use of science and technology, humanity has brought great harm upon itself with its wartime innovations, but it has also helped society advance.

Shacovik Flores

See also *Vol. 1, Sec. 2*: Submarine; *Vol. 1, Sec. 3*: Machine/Gatling Gun; Railroads; Repeating Rifle; Telegraph; *Vol. 2, Sec. 3*: M4 Sherman Tank

Further Reading

Fitzgerald, Gerard J. 2008. “Chemical Warfare and Medical Response during World War I.” *American Journal of Public Health* 98, no. 4 (April): 611–25.

Marcot, Roy M. 2002. *Spencer Repeating Firearms*. n.p.: Andrew Mowbray.

“North Carolinians and the Great War. Documenting the American South.” University of North Carolina at Chapel Hill Libraries. <http://docsouth.unc.edu/wwi/>, accessed August 29, 2018.

“World War I.” North Carolina Digital History. Learn NC. <http://www.learnnc.org/lp/editions/nchist-newcentury/3.0>, accessed August 29, 2018.

“WWI: Old North State and the ‘Kaiser Bill.’” Online exhibit. State Archives of North Carolina. <http://www.archives.ncdcr.gov/wwI/OldNorthState/index.htm>, accessed August 29, 2018.

Mining Sulfur Fluidically. See Frisch Process

Motion Picture Camera

The motion picture camera, also called the film camera or cine-camera, takes photographs in rapid sequence. Each image it takes is called a “frame.” When frames are played back in sequence and at a

specific speed, they create the illusion of motion. The invention of the motion picture camera revolutionized the film industry in America. From the advancements made by the kinetoscope and the kinetograph, cameras and video recorders evolved from the basic standard set by Thomas Edison's (1874–1931) invention to the digital cameras of 21st-century movie making. The motion picture camera made it possible for Americans to shape culture with entertainment, rally troops with war propaganda, and more.

The first design of the motion picture camera was the kinetoscope, a large box used for the viewing of motion films. It involved a cylinder coated with collodion, an agent that was used in early photo development (1851). However, collodion was too coarse to use on the cylinder and failed to provide a clear picture. The very first motion picture camera was patented in 1876, and many major variations of the invention were devised in England, France, and Britain. Before the invention of the motion picture camera, Edison created the kinetoscope. It was the sister invention to the movie camera and was significant for the development of mechanisms used in the motion picture camera.

The Edison motion picture viewing device, or kinetoscope, was first created sometime between 1889 and 1892 by Thomas Edison and William Kennedy-Laurie Dickson. It was the first commercially successful moving image invention that used a patented electric motor-powered sprocket technology not used in any other variation. The invention was inspired by a lecture from Eadweard Muybridge, who used a zoopraxiscope (created in 1879) to simulate the motion of animals and create the illusion of movement. Although Edison provided the concept for the machine, he relied heavily on Dickson's knowledge of photography to help the idea come to fruition. Dickson was given control of the experimentation needed to develop the camera and eventually developed a kinetographic camera in 1891 with the Edison Lab team.

Celluloid sheets, invented by George Eastman in 1889, were next used on the cylinder to provide a much cleaner recorded image. The first motion picture ever recorded in the United States was called *Monkeyshines, No. 1*. The short film was of one of Thomas Edison's employees, taken to test the effectiveness of the cylinder format in the kinetoscope. The cylinder format was

later changed around 1890 to a film strip format after Edison traveled to Europe and obtained new concepts for the invention, such as flexible, perforated film that could be carried along smoothly by sprockets.

The kinetograph, or motion picture camera, was developed and patented by Edison in 1891 shortly after the kinetoscope and is the sister invention to the motion picture viewing device. The kinetograph took video by using an intermittent mechanism composed of an electrically motorized perforated-film-and-sprocket system that synched the film and the shutter so that the camera would stop each frame before the lens long enough for the shutter to open and expose the film. In comparison to other motion picture cameras that were invented around the world, Edison's film-and-sprocket system allowed for a faster film frame rate and a smoother recording process without mechanical errors or the cumbersome method of hand-feeding film into the device. The film taken with the kinetograph could then be played back at some speed to create the illusion of movement. It could shoot up to 50 feet of film at 40 to 46 frames per second for up to 30 minutes. The kinetograph set the standard for future filming inventions and technology and revolutionized the filming process, helping popularize the film industry in the United States. The perforated-film-and-sprocket system used in the kinetograph is still used in modern motion picture cameras because many film producers prefer a more traditional approach to filming, and it provides a greater depth of field and larger exposure latitude. Many film producers continue to prefer film cameras and use the depth of field to grab the audience's attention or use the extended exposure latitude to darken details not needed in movie shots.

In 1911, Bell and Howell Company introduced the first metal movie picture camera, and in 1932, the Mitchell Technicolor camera allowed movies to be shot in color using three strips of film filtered to capture purple, green, and red. In 1923, Eastman Kodak introduced 16-mm film stock as a low-cost alternative to 35-mm film stock. Thus, the amateur movie-making market was born. By the 1950s, middle-class American households generally owned movie cameras with which they filmed a variety of "home movies," generally commemorating birthdays and holidays.

In the 21st century, digital movie cameras have come to dominate the movie-making industry and movie camera market. In fact, digital movie cameras for the mass consumer market have made low-cost, independent movie-making possible, opening new fields of movie production.

Serena Castillo

See also Camera; Celluloid; Eastman, George; Edison, Thomas; Kinetoscope; Photographic Film; *Vol. 3, Sec. 1*: Land, Edwin H.; *Vol. 3, Sec. 2*: Digital Photography

Further Reading

- Brown, Richard, and Barry Anthony. 2017. *The Kinetoscope: A British History*. Barnet, UK: John Libbey.
- Dickson, W. K. L., and Antonia Dickson. 2002. *History of the Kinetograph, Kinetoscope and Kinetophonograph*. Facsimile Edition. New York: The Museum of Modern Art.
- Hendricks, Gordon. 1966. *The Kinetoscope: America's First Commercially Successful Motion Picture Exhibitor*. New York: Beginnings of the American Film.
- Musser, Charles. 1995. *Thomas A. Edison and His Kinetographic Motion Pictures*. New Brunswick, NJ: Rutgers University Press.
- Phillips, Ray. 1997. *Edison's Kinetoscope and Its Films: A History to 1896*. Contributions to the Study of Popular Culture. New York: Praeger.
- Spehr, Paul. 2008. *The Man Who Made Movies: W. K. L. Dickson*. Barnet, UK: John Libbey.

National Consumers League

The National Consumers League (NCL) was founded in 1891 as part of the Progressive Era's reform impulse. In 1891, the Consumer's League took form in New York, Massachusetts, Pennsylvania, and Illinois. In 1899, the leagues united to become the NCL, adopting the motto "Investigate, agitate and legislate."

Florence Kelley served as president of the NCL from 1899 to 1932. She graduated from Cornell in 1882 and then went on to study law and government at the

University of Zurich. Kelley became a socialist and married a Russian medical student. They had three children together before she fled from his abuse and moved to Hull House in Chicago. While raising her three children alone, Kelley took night classes at Northwestern Law School and earned her degree. In 1895 Kelley's lifelong battle with the courts began when she persuaded the Illinois state government to help fund her research on industrial working conditions in Chicago.

In 1908, the NCL prepared the brief used by Louis Brandeis, a lawyer in the *Muller v. Oregon* case, in which the U.S. Supreme Court enforced a state law for the maximum of work hours for women. The NCL drafted the nation's first minimum wage law, which was enacted in Massachusetts in 1912 and spread to 12 other states within a few years. During the early 1900s, the NCL participated in promoting the Meat Inspection Act of 1904 and the Pure Food and Drug Act of 1906. Understanding the pressures of competition in the workforce, the NCL placed responsibility on not only the employer but also the consumer.

As an early attempt to encourage employers to volunteer information on working conditions, the NCL implemented a "white list" and "white label." Though the word "white" was meant as a contrast to the term "blacklist," the action ultimately repelled African Americans from joining the movement. However, the label was successful in recruiting middle-class women and educating them on labor practices. Jewish women also played a role in the NCL and were significantly more likely to support women in the workforce and activism.

During the Progressive Era, the NCL gained popularity due to the organization's demand for ethical consumption. Upon Kelley's death, Lucy Randolph Mason directed the NCL, followed by Mary Dublin (Keyserling) from 1938 to 1940. Eleanor Roosevelt served as the vice president of the NCL and testified on behalf of the organization on numerous occasions. During this time, the NCL was most focused on passing the 1938 federal Fair Labor Standards Act. This important legislation addressed issues that included child labor, minimum wage, restrictions on hours worked, and industrial homework. In addition, the NCL also advocated for national health insurance,

improved food and drug safety laws and federal pesticide monitoring, social security legislation (namely for the elderly and the disabled), and unemployment insurance.

In 1943, Elizabeth Magee directed the NCL; she moved the organization's office to Cleveland, Ohio, her hometown. Magee placed the group's emphasis on equal pay for equal work for women, extension of fair labor laws to migratory workers, guaranteed compensation for workplace accidents, and disability coverage under social security. At the end of Magee's term as director, in the fall of 1958, the NCL office moved back to the East Coast and to Washington, D.C.

Vera Waltman Mayer and Sarah Newman led the NCL into and throughout the 1960s. During this time, the organization focused on consumer protection, prioritizing issues such as health assistance for migratory workers, Medicare and Medicaid, wholesome meat and poultry, truth-in-packaging legislation, food additive and coloring testing, and worker safety in atomic industries.

During the 1970s and 1980s, the executive director, Sandra Willett Jackson, created the Assertive Consumer project in an attempt to increase consumer education. During this period, influential figures such as Esther Peterson served as vice presidents of the NCL. Peterson was a renowned labor and consumer leader and regularly testified on behalf of the NCL. She went on to become head of the White House Office of Consumer Affairs under President Jimmy Carter. Before that, Peterson also served as consumer advisor to Presidents John F. Kennedy and Lyndon Johnson. The NCL established the Alliance Against Fraud in Telemarketing and the Child Labor Coalition in the 1980s. Today, the NCL advocates for the safe use of medication, better working conditions for migrant farmworker families and teen workers, improved product safety, and accurate food and beverage product labeling.

Adrienne Harwell

Further Reading

Storrs, Landon R. Y. 2000. *Civilizing Capitalism: The National Consumers' League, Women's Activism, and Labor Standards in the New Deal Era*. Chapel Hill: University of North Carolina Press.

National Institutes of Health (NIH)

Operating and conducting research on its main campus in Bethesda, Maryland, the National Institutes of Health is a U.S. government organization that calls attention to and supports biomedical and health-related studies. The agency is also a part of the U.S. Department of Health and Human Services and is known for its significant findings and research seeking to discover more ways to save lives each day. The NIH has over two dozen branches or elements called Centers and Institutes.

While the National Institutes of Health essentially endeavors to strengthen health, it has a variety of goals. It seeks to innovate and develop resources to prevent the spread of illness worldwide and to raise the country's welfare. In all it does, it relies on the principles of science.

In the late 1880s, the NIH was established in a one-room laboratory within the Marine Hospital Service (MHS), offering medical assistance on travelers who arrived on ships and had symptoms of infectious diseases such as yellow fever and cholera. As such occasions became frequent, Congress funded the MHS, later changing its name to Public Health Services and moved it from New York to Massachusetts into a lab at Harvard Medical School. With the Ransdell Act of 1930, the institute was presented with \$750,000 to build two buildings, which later expanded into numerous centers. Finally, the organization became the National Institutes of Health in 1948.

The main office at the NIH establishes regulations and policies, administering affairs throughout the NIH. The director of the national institute is currently Dr. Francis S. Collins, who earned his PhD in physical chemistry from Yale University in 1974. He assumed this post in August 2009. Collins didn't want to focus only on so-called the "big three" diseases AIDS, TB, and malaria. He wanted more research on other fatal but nontransmissible ailments such as cancer, heart disease, and diabetes. The NIH secured additional funding from the private sector, including from the Bill & Melinda Gates Foundation and the Wellcome Trust, a global charity based in London.

Investing over \$32 billion in research each year, the NIH awards grants to more than 2,500 institutions

such as medical schools and universities and well as studies around the globe.

Hiba Mouri

See also *Vol. 3, Sec. 2*: Gates, Bill

Further Reading

Ginther, Donna K., Walter T. Schaffer, Joshua Schnell, Beth Masimore, Faye Liu, Laurel L. Haak, and Raynard Kington. 2011. "Race, Ethnicity, and NIH Research Awards." *Science (New York, NY)* 333, no. 6045: 1015.

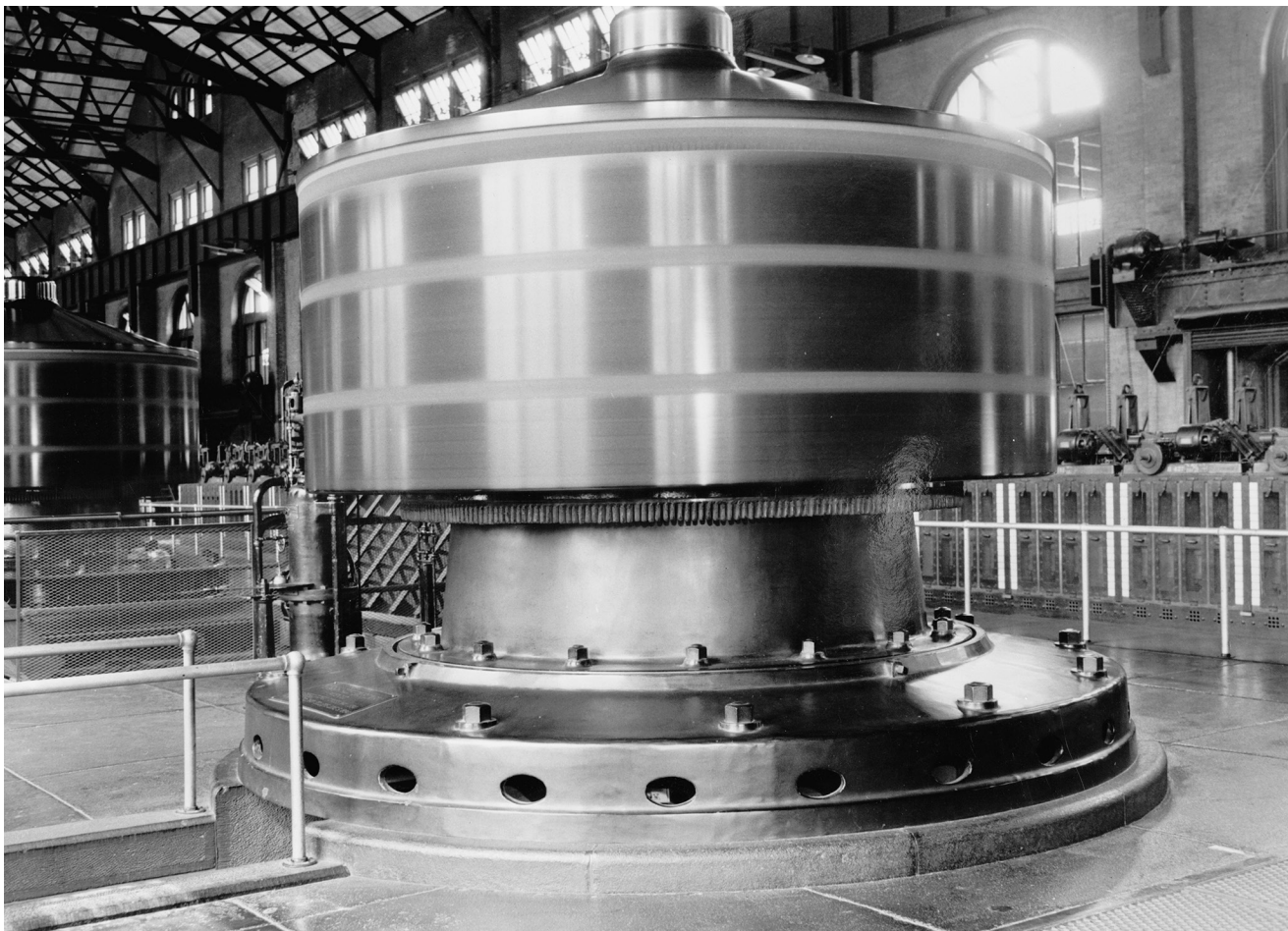
Hayden, Erika Check. 2012. "DNA Donor Rights Affirmed: NIH Committee Urges That Genome Study Subjects Be Told of Medically Relevant Results." *Nature* 483, no. 7390: 387.

Journal of the National Cancer Institute: JNCI. Washington, D.C.: U.S. Department of Health, Education, and Welfare, Public Health Service, National Institutes of Health.

Niagara Falls Power Plant

The Niagara Falls power plant began the world's electrical age. It was the first plant to supply massive amounts of electrical power to consumers at reasonable prices, and it spurred the electrical appliance, aluminum, and electrochemical industries. The power of waterfalls remains preeminent in electrical generation throughout the world.

The Niagara Falls have an almost unbelievable average flow of 100,000 cubic feet per second, with a



The Edward D. Adams Power Plant at Niagara Falls, New York, was the first large-scale alternating current-generating plant in the world. Built in 1895, the plant could generate 50,000 horsepower in electricity. (Library of Congress)

peak of 225,000 cubic feet per second. There is a peak period of flow from April to November. There is even a daily variation in the flow, with the peak flow at 9 a.m. and the lowest flow at 9 p.m. German electrical engineer Sir Werner von Siemens estimated in 1888 that “the amount of water falling over Niagara is equal to 100,000,000 tons of coal an hour.” Sir Siemens calculated that “if steam boilers could be erected vast enough to exhaust daily the whole coal output of the earth, the steam generated would barely suffice to pump back again the water flowing over Niagara Falls.”

A battle for the Niagara power plant contract went on between J. P. Morgan and Thomas Edison’s direct current (DC) system versus George Westinghouse’s alternating current (AC). A commission was formed in 1890 to explore whether DC or AC power generation should be selected. The long-distance transmission of AC power to cities such as Telluride, Colorado, and Frankfurt, Germany, helped the commission to select AC and the Westinghouse system. Finally, the success of Westinghouse’s “White City” at the 1893 Chicago World’s Fair was the tipping point. In 1893, Westinghouse’s AC system was selected with a contract to build two 5,000-horsepower generators. Although Westinghouse got the largest part of the contract, General Electric also ended up with some lucrative contracts for transformers and transmission lines.

General Electric’s work on the transformers became critical to Niagara’s success. The AC system and transformers allowed for long-distance transmission of power, which a DC system could not achieve. These transformers stepped up the voltage from a generated 2,000 volts to 10,000 volts as well as changing the two-phase current to three phases. The current at 10,000 volts was then transmitted through bare copper cable (on thousands of insulated wooden poles) to Buffalo, New York, 26 miles away. Full transmission would begin in 1896. General Electric transformers then stepped down the voltage to 110 volts for general lighting and 370 volts for Buffalo’s street-railway system. In the end, Westinghouse’s great victory generated vital profits for General Electric as the Panic of 1893 continued until 1896, when General Electric and Westinghouse started to work together for the good of the Niagara project. Morgan also realized that any

further internal competition would cost the overall project and his syndicate money. Niagara was to be the world’s largest engineering project, requiring Morgan to bring in other financiers such as August Belmont, John Astor, and the Vanderbilts as investors. With Thomas Edison bought out, Morgan converted General Electric to AC technology.

The real man behind the Niagara power project was neither Westinghouse nor Edison nor Morgan, but Nikola Tesla. It was Tesla’s patents that supplied the AC power technology. Tesla’s patents had made AC technology the future. The first power came on at Niagara on August 26, 1895. On that August day, Dynamo No. 2 went online, supplying current to the Pittsburgh Reduction Company. The initial power went to the electrochemical plants nearby. Dynamo No. 1 didn’t come on stream until September 30, at which time the directors of Cataract Construction Company and Westinghouse, plus assorted millionaires, came to celebrate. Two important figures were not present—Morgan, who came later in October, and Tesla. As the plaque at the falls would reflect, Westinghouse gave all the credit to Tesla. In total, 13 of Tesla’s patents were used in the creation of the Niagara power plant. Still, the bitterness of the “war of the currents” had created a bias against Tesla in the New York press controlled by Morgan. The *New York Times* found a way to hail the event without mentioning Tesla, while most other papers hailed Tesla as the equal of Edison in the triumph of the falls. It was a great victory for Westinghouse Electric, but Westinghouse spent time at Pittsburgh Reduction Company, further studying the wonders of aluminum smelting rather than celebrating.

One of the great results of the Niagara power station was the rise of the American electrochemical industry. The two biggest customers of Niagara were the Pittsburgh Reduction Company and the Carborundum Company. The Pittsburgh Reduction Company (the future Aluminum Company of America, or ALCOA) contracted for 5,000 of the 15,000 available horsepower. Niagara finally made the production and use of aluminum economically feasible.

Niagara power’s other big customer was the Carborundum Company. Carborundum was an artificial abrasive composed of aluminum oxide. These alumina

crystals were produced by electrochemical processing, as pure aluminum was. Larger, colored alumina crystals found in nature are sapphires and rubies. The fine artificial alumina crystals are extremely hard, making them ideal for grinding and cutting wheels. Within a year, a massive electrochemical industry grew up around Niagara, including plants producing sodium, soda ash, sodium peroxide, and calcium carbide. By 1897, 12,500 of the 13,500 horsepower available for local consumption went to electrochemical plants. Westinghouse enjoyed visiting these plants, since he always had a fascination with metallurgy. The aluminum industry owes a great deal to Westinghouse.

Within a few years, Niagara had become a major production area for steelmaking ferroalloys such as ferrosilicon and ferrochrome. These ferroalloys required power levels for production that were unavailable until the Niagara Falls power plant. The massive amount of workers needed to build the power system and operate the electrochemical plants required a planned worker town of houses, which would be the first in the country to be lighted and heated by electricity.

Industrialist William Love hoped to emulate Westinghouse's industrial utopian town of Wilmerding, Pennsylvania, by creating an industrial utopia for electrochemical workers. The effort resulted in a mile-long town along the wastewater canal known as the Love Canal. The town failed to grow and became the LaSalle area of Niagara. It would become famous for the old toxic electrochemicals that caused a strange "outbreak" of cancer in the 1970s and an example of the costly legal battles created by industrial pollution.

Buffalo, New York, had originally been the reason for the Niagara project. Buffalo received the necessary amount of current to be applied in street arc lights, incandescent lights in homes, and electric motors in factories, as well as used by the Buffalo Railway Company for streetcars. In 1901, the Pan-American Exposition came to Buffalo to show the world the future of electricity. The exposition highlighted electrical appliances that were in use in Buffalo such as sewing machines, home lighting, neon lights, electric elevators, and laundry machines.

Quentin R. Skrabec

See also Electricity, War of the Currents; Tesla, Nikola; World's Fairs

Further Reading

Berton, Pierre. 2009. *Niagara: A History of the Falls*. Albany: State University of New York Press.

Grant, John, and Ray Jones. 2006. *Niagara Falls: An Intimate Portrait*. Guilford, CT: Insiders/Globe Pequot.

Jonnes, Jill. 2003. *Empires of Light*. New York: Random House.

MacLaren, Malcolm. 1943. *The Rise of the Electrical Industry during the Nineteenth Century*. Princeton, NJ: Princeton University Press.

McGreevy, Patrick. 2009. *Imagining Niagara: The Meaning and Making of Niagara Falls*. Amherst: University of Massachusetts.

Seifer, Marc. 1998. *Wizard: The Life and Times of Nikola Tesla*. New York: Citadel.

Primary Document: Excerpt from Nikola Tesla's Commemoration Address for the Niagara Falls Power Plant (1897)

The power plant at Niagara Falls was designed by Nikola Tesla and George Westinghouse in 1895. The plant represented the final skirmish in the battle between Tesla's Alternating Current and Edison's Direct Current. Tesla gave the commemoration address for the Niagara Falls Power Plant in 1897. The Electrical Review reprinted his speech that same month. The following is an excerpt of that speech.

ON ELECTRICITY

by Nikola Tesla

(The Address On the Occasion of the Commemoration of the Introduction of Niagara Falls Power in Buffalo At the Ellicott Club, January 12, 1897)

Electrical Review, January 27, 1897

. . . I have referred to the merging together of the various sciences or departments of research, and to a certain perception of intimate connection between the manifold and apparently different forces and phenomena. Already we know, chiefly through the efforts of a bold pioneer, that light, radiant heat, electrical and magnetic actions are closely related, not to say identical. The chemist professes that the effects of combination and separation of bodies he observes are due to electrical forces, and the physician and physiologist will tell you that even life's progress is electrical. Thus electrical science has gained a universal meaning, and with right this age can claim the name "Age of Electricity."

I wish much to tell you on this occasion—I may say I actually burn for desire of telling you—what electricity really *is*, but I have very strong reasons, which my coworkers will best appreciate, to follow a precedent established by a great and venerable philosopher, and I shall not dwell on this purely scientific aspect of electricity.

There is another reason for the claim which I have before stated which is even more potent than the former, and that is the immense development in all electrical branches in more recent years and its influence upon other departments of science and industry. To illustrate this influence I only need to refer to the steam or gas engine. For more than half a century the steam engine has served the innumerable wants of man. The work it was called to perform was of such variety and the conditions in each case were so different that, of necessity, a great many types of engines have resulted. In the vast majority of cases the problem put before the engineer was not as it should have been, the broad one of converting the greatest possible amount of heat energy into mechanical power, but it was rather the specific problem of obtaining the mechanical power in such form as to be best suitable for general use. As the reciprocating motion of the piston was not convenient for practical purposes, except in very few instances, the piston was connected to a crank, and thus rotating motions was obtained, which was more suitable and preferable, though it involved numerous disadvantages incident to the crude and wasteful means employed. But until quite recently there were at the disposal of the engineer, for the transformation and transmission of the motion of the piston, no better means than rigid

mechanical connections. The past few years have brought forcibly to the attention of the builder the electric motor, with its ideal features. Here was a mode of transmitting mechanical motion simpler by far, and also much more economical. Had this mode been perfected earlier, there can be no doubt that, of the many different types of engine, the majority would not exist, for just as soon as an engine was coupled with an electric generator a type was produced capable of almost universal use. From this moment on there was no necessity to endeavor to perfect engines of special designs capable of doing special kinds of work. The engineer's task became now to concentrate all his efforts upon one type, to perfect one kind of engine—the best; the universal, the engine of the immediate future; namely, the one which is best suitable for the generation of electricity. The first efforts in this direction gave a strong impetus to the development of the reciprocating high speed engine, and also to the turbine, which latter was a type of engine of very limited practical usefulness, but became, to a certain extent, valuable in connection with the electric generator and motor. Still, even the former engine, though improved in many particulars, is not radically changed, and even now has the same objectionable features and limitations. To do away with these as much as possible, a new type of engine is being perfected in which more favorable conditions for economy are maintained, which expands the working fluid with utmost rapidity and loses little heat on the walls, an engine stripped of all usual regulating mechanism—packings, oilers and other appendages—and forming part of an electric generator; and in this type, I may say, I have implicit faith.

The gas or explosive engine has been likewise profoundly affected by the commercial introduction of electric light and power, particularly in quite recent years. The engineer is turning his energies more and more in this direction, being attracted by the prospect of obtaining a higher thermodynamic efficiency. Much larger engines are now being built, the construction is constantly improved, and a novel type of engine, best suitable for the generation of electricity, is being rapidly evolved.

There are many other lines of manufacture and industry in which the influence of electrical development has been even more powerfully felt. So, for instance, the manufacture of a great variety of articles

of metal, and especially of chemical products. The welding of metals by electricity, though involving a wasteful process, has, nevertheless, been accepted as a legitimate art, while the manufacture of metal sheet, seamless tubes and the like affords promise of much improvement. We are coming gradually, but surely, to the fusion of bodies and reduction of all kinds of ores—even of iron ores—by the use of electricity, and in each of these departments great realizations are probable. Again, the economical conversion of ordinary currents of supply into high-frequency currents opens up new possibilities, such as the combination of the atmospheric nitrogen and the production of its compounds; for instance, ammonia and nitric acid, and their salts, by novel processes.

The high-frequency currents also bring us to the realization of a more economical system of lighting; namely by means of phosphorescent bulbs or tubes, and enable us to produce with these appliances light of practically any candle-power. Following other developments in purely electrical lines, we have all rejoiced in observing the rapid strides made, which, in quite recent years, have been beyond our most sanguine expectations. To enumerate the many advances recorded is a subject for the reviewer, but I can not pass without mentioning the beautiful discoveries of Lenart and Roentgen, particularly the latter, which have found such a powerful response throughout the scientific world that they have made us forget, for a time, the great achievement of Linde in Germany, who has effected the liquefaction of air on an industrial scale by a process of continuous cooling: the discovery of argon by Lord Rayleigh and Professor Ramsay, and the splendid pioneer work of Professor Dewar in the field of low temperature research. The fact that the United States have contributed a very liberal share to this prodigious progress must afford to all of us great satisfaction. While honoring the workers in other countries and all those who, by profession or inclination, are devoting themselves to strictly scientific pursuits, we have particular reasons to mention with gratitude the names of those who have so much contributed to this marvelous development of electrical industry in this country. Bell, who, by his admirable invention enabling us to transmit speech to great distances, has profoundly affected our commercial and social relations, and even our very mode of life; Edison, who, had he not done anything else

beyond his early work in incandescent lighting, would have proved himself one of the greatest benefactors of the age; Westinghouse, the founder of the commercial alternating system; Brush, the great pioneer of arc lighting; Thomson, who gave us the first practical welding machine, and who, with keen sense, contributed very materially to the development of a number of scientific and industrial branches; Weston, who once led the world in dynamo design, and now leads in the construction of electric instruments; Sprague, who, with rare energy, mastered the problem and insured the success of practical electrical railroading; Acheson, Hall, Willson and others, who are creating new and revolutionizing industries here under our very eyes at Niagara. Nor is the work of these gifted men nearly finished at this hour. Much more is still to come, for fortunately, most of them are still full of enthusiasm and vigor. All of these men and many more are untiringly at work investigating new regions and opening up unsuspected and promising fields. Weekly, if not daily, we learn through the journals of a new advance into some unexplored region, where at every step success beckons friendly, and leads the toiler on to hard and harder tasks.

But among all these many departments of research, these many branches of industry, new and old, which are being rapidly expanded, there is one dominating all others in importance—one which is of the greatest significance for the comfort and welfare, not to say for the existence, of mankind, and that is the electrical transmission of power. And in this most important of all fields, gentlemen, long afterwards, when time will have placed the events in their proper perspective, and assigned men to their deserved places, the great event we are commemorating today will stand out as designating a new and glorious epoch in the history of humanity—an epoch grander than that marked by the advent of the steam engine. We have many a monument of past ages: we have the palaces and pyramids, the temples of the Greek and the cathedrals of Christendom. In them is exemplified the power of men, the greatness of nations, the love of art and religious devotion. But that monument at Niagara has something of its own, more in accord with our present thoughts and tendencies. It is a monument worthy of our scientific age, a true monument of enlightenment and of peace. It signifies the subjugation of natural forces to the service of man, the discontinuance of

barbarous methods, the relieving of millions from want and suffering. No matter what we attempt to do, no matter to what fields we turn our efforts, we are dependent on power. Our economists may propose more economical systems of administration and utilization of resources, our legislators may make wiser laws and treaties, it matters little; that kind of help can be only temporary. If we want to reduce poverty and misery, if we want to give to every deserving individual what is needed for a safe existence of an intelligent being, we want to provide more machinery, more power. Power is our mainstay, the primary source of our many-sided energies. With sufficient power at our disposal we can satisfy most of our wants and offer a guaranty for safe and comfortable existence to all, except perhaps to those who are the greatest criminals of all—the voluntarily idle.

But we shall not satisfy ourselves simply with improving steam and explosive engines or inventing new batteries; we have something much better to work for, a greater task to fulfill. We have to evolve means for obtaining energy from stores which are forever inexhaustible, to perfect methods which do not imply consumption and waste of any material whatever. Upon this great possibility, which I have long ago recognized, upon this great problem, the practical solution of which means so much for humanity, I have myself concentrated my efforts since a number of years, and a few happy ideas which came to me have inspired me to attempt the most difficult, and given me strength and courage in adversity. Nearly six years ago my confidence had become strong enough to prompt me to an expression of hope in the ultimate solution of this all dominating problem. I have made progress since, and have passed the stage of mere conviction such as is derived from a diligent study of known facts, conclusions and calculations. I now feel sure that the realization of that idea is not far off. But precisely for this reason I feel impelled to point out here an important fact, which I hope will be remembered. Having examined for a long time the possibilities of the development I refer to, namely, that of the operation of engines on any point of the earth by the energy of the medium, I find that even under the theoretically best conditions such a method of obtaining power can not equal in economy, simplicity and many other

features the present method, involving a conversion of the mechanical energy of running water into electrical energy and the transmission of the latter in the form of currents of very high tension to great distances. Provided, therefore, that we can avail ourselves of currents of sufficiently high tension, a waterfall affords us the most advantageous means of getting power from the sun sufficient for all our wants, and this recognition has impressed me strongly with the future importance of water power, not so much because of its commercial value, though it may be very great, but chiefly because of its bearing upon our safety and welfare. I am glad to say that also in this latter direction my efforts have not been unsuccessful, for I have devised means which will allow us the use in power transmission of electromotive forces much higher than those practicable with ordinary apparatus. In fact, progress in this field has given me fresh hope that I shall see the fulfillment of one of my fondest dreams; namely, the transmission of power from station to station without the employment of any connecting wire. Still, whatever method of transmission be ultimately adopted, nearness to the source of power will remain an important advantage.

Gentlemen, some of the ideas I have expressed may appear to many of you hardly realizable; nevertheless, they are the result of long-continued thought and work. You would judge them more justly if you would have devoted your life to them, as I have done. With ideas it is like with dizzy heights you climb: At first they cause you discomfort and you are anxious to get down, distrustful of your own powers; but soon the remoteness of the turmoil of life and the inspiring influence of the altitude calm your blood; your step gets firm and sure and you begin to look—for dizzier heights. I have attempted to speak to you on "Electricity," its development and influence, but I fear that I have done it much like a boy who tries to draw a likeness with a few straight lines. But I have endeavored to bring out one feature, to speak to you in one strain which I felt sure would find response in the hearts of all of you, the only one worthy of this occasion—the humanitarian. In the great enterprise at Niagara we see not only a bold engineering and commercial feat, but far more, a giant stride in the right direction as indicated both by exact science and philanthropy. Its success is a signal for the utilization of water powers all

over the world, and its influence upon industrial development is incalculable. We must all rejoice in the great achievement and congratulate the intrepid pioneers who have joined their efforts and means to bring it about. It is a pleasure to learn of the friendly attitude of the citizens of Buffalo and of the encouragement given to the enterprise by the Canadian authorities. We shall hope that other cities, like Rochester on this side and Hamilton and Toronto in Canada, will soon follow

Buffalo's lead. This fortunate city herself is to be congratulated. With resources now unequaled, with commercial facilities and advantages such as few cities in the world possess, and with the enthusiasm and progressive spirit of its citizens, it is sure to become one of the greatest industrial centers of the globe.

Source: Tesla, Nikola. "On Electricity." *Electrical Review*, January 27, 1897.

Office Technology (Pre–World War II)

The second half of the 19th century witnessed a profound transformation in American offices as well as the technologies needed to administer the increasing workload resulting from an increase in population and the advance of American industry. As the country expanded westward, land, railroad, telegraph—and soon telephone—offices required efficient means for creating, organizing, and distributing paperwork as well as tabulating and recording finances and accounts. By the time of the Centennial Exposition held in Philadelphia in 1876, great advances in paper fastening and calculation, among other products, demonstrated how invention and innovation met the pressing needs of the work environment.

George McGill, an inventor born in Lancaster, Ohio, and operating in New York City, patented a brass fastener in 1866 and a device to cut a hole in the paper to accommodate the fastener the following year. This process required the operator to press a hole in the paper and then insert the fastener by hand. McGill went on to improve his device and demonstrate it at the International Exhibition in Philadelphia in 1876. Within one year, McGill patented a device capable of inserting and pressing a preformed fastener in one movement, but it still required the operator to load one staple at a time.

The name "stapler" can be found as early as 1888, but it wasn't until well into the 20th century that the term gained wide acceptance. The variety in names was due in part to the sheer diversity in materials and shapes used to bind papers together beyond the

now-standard staple. This included staples cast from spools of wire or strips of flat metal, along with straight pins and bent pieces of wire. In 1909, a device was patented by the Clipless Paper Fastener Company that joined documents by punching a hole and burr straight through the papers. The variety of shapes, calibers, and materials of staples contributed to the transformation and standardization of the stapler during the 1930s and 1940s.

By and large, each type of stapler offered on the market used a variety of staple unique to that particular model, a situation that proved inconvenient from the perspective of office supply as well as product marketing. An office that had difficulty in obtaining particular staples or desired to upgrade devices would have to take into consideration the accessibility of particular calibers of staple; meanwhile, a company that could offer a staple interchangeable with other models could gain a competitive edge. The answer to this problem was developed in part with the first "magazine" stapler patented as early as 1878. By the late 1920s, a magazine of over 100 glued, attached staples could be easily inserted into a stapler. The introduction of standard calibers of staples in 1940 made the convenient and rapid-fire magazine stapler the dominant fastener in American offices.

Traditional needle and thread or adhesives, along with the new generation of staplers, still presented the problem of documents being damaged should the owner decide to separate them at a later date. This need was rectified by the invention of the modern paper clip by William D. Middlebrook of Waterbury, Connecticut, who was master mechanic for over 30

years at the Oakville Pin Company. While in this capacity, he patented a paper clip along with a machine to create it in 1899.

The “classic” paper clip or “letter clip” is a bent metal wire that fastens papers by exerting pressure rather than perforating a hole, and it can easily be removed without damaging the paper and stored without becoming tangled with other clips. George McGill, already recognized for his work in developing the fastening staple and other office equipment, also patented a paper clip in 1903. Cushman and Denison, a manufacturer of metal products operating in New York City, obtained manufacturing rights from Middlebrook and marketed the paper clip under the name “GEM.” A number of clips of different shapes were marketed in Great Britain and Europe under the “gem” name, which had some influence in office supply circles in the United States. Paper clips are sometimes referred to as “gem clips” based on this nomenclature.

Another version of the paper clip popular in American offices was the “gothic” variety patented in 1934 and sometimes referred to as the “perfected gem paper clip.” Its pointed sides resemble the buttresses of a cathedral or the arches of a gothic window in comparison with the rounded, “Romanesque” edges of the classic paper clip. Despite the variety of patents granted for different shapes and materials, paper clips by 1940 remained similar in design to those introduced at the turn of the century.

Edwin Moore founded the Moore Push-Pin Company in 1904 in Germantown, Pennsylvania, just outside of Philadelphia. Moore invented the pushpin in 1900, and his company continues to develop office equipment that he originally developed, including picture hangers and map pins. Thumbtacks are typically referred to as “drawing pins” when used to attach work to drawing boards in drafting. During the 1920s, the concept of the mechanical stapler and the pushpin were combined with the Pinzit machine, which inserted a straight pin through paper by means of a special push device.

The development of adhesive tape for office environments began with the innovation of masking tape by Richard Drew for the 3M Corporation (the Minnesota Mining and Manufacturing Company) in 1925 in St. Paul, Minnesota. Masking tape was

invented for the painting needs of the automotive industry, where an even and clean-peeling adhesive was essential for painting and trimming parts of cars. The principle of a clean adhesive on a convenient roll was a significant development and gained in popularity. Clear, cellophane tape was also originally intended for industrial purposes; in this case, the need to waterproof parts to be used in train cars. Drew experimented with rolls of cellophane originally intended as a material for packaging his masking tape. By 1930, the first rolls of cellophane tape were marketed under the trademark “Scotch Tape,” which has entered into common American English as a colloquialism for any brand of cellophane tape. At the time of the product’s creation, “scotch” was a slang word for “cheap” or “stingy,” alluding to an incident during the product testing of masking tape where Drew was asked by testers to add more adhesive to his tape.

Mechanical calculators or adding machines have a long history as a favored pursuit of philosophers and inventors for centuries. It was not until the middle of the 19th century that a durable, mass-produced mechanical calculator entered the market. French entrepreneur and inventor Charles Xavier Thomas de Colmar created the “Arithmometer” in 1851. Contained within a wooden box, an Arithmometer could directly add or subtract numbers and perform long division and multiplication by means of a series of adjustable levers.

Improvement in interface, particular the addition of numbered buttons, marked the transition to “modern” mechanical calculators. Dorr Felt, an industrialist and inventor based in Chicago, Illinois, invented the first key-driven mechanical calculator in 1886 and named it the “Comptometer.” As opposed to the arithmometer, which required the operator to turn additional levers to complete a function, the Comptometer automatically calculated after one pressed the numbered keys. It possessed a keyboard of eight columns with nine keys each, which further allowed the operator to enter all the digits of a large number simultaneously. The device could add and subtract directly, but it required a series of additions and subtractions to multiply or divide. This ease of use allowed the Comptometer to maintain a level of prominence in the office

even after the innovation of electric calculators in the middle of the 20th century.

Felt brought his invention to the Chicago businessman Robert Tarrant, and together they founded the Felt & Tarrant Manufacturing Company and mass-produced the Comptometer in its varying stages of evolution. The company marketed the Comptometer until its merger with Victor Adding Machine Company in 1961, a point that marked a slow evolution of the calculator industry to electronic models. A Comptometer was roughly the size of a shoebox and made of polished metal, with rows of buttons on the top along with a number display and a small lever to the side that cleared the results when pulled. The introduction of the clearing lever was advertised as “the machine gun of the office” in reference to the technological advances in rapid-fire weapons during the Great War. In the 1930s, a number of special electric-powered models were introduced, although they did not outsell the traditional mechanical Comptometers.

Machinist William S. Burroughs founded in 1886 what became the Burroughs Adding Machine Company to market his invention, a mechanical “calculating machine.” In 1892, he commenced distribution of a mechanical calculator capable of printing a paper copy of its tabulations. The Dalton Adding Machine was created in 1902 and was the first calculator to have only 10 numerical buttons. However, the Facit-T model created in 1932 was the first 10-key version to gain widespread sales and distribution. A longtime producer of calculators and typewriters for American offices, the Burroughs Company also marked an important transition point between mechanical calculators and the rise of modern mainframe computers.

Sean P. Phillips

See also Crayons; Punch Card Tabulator; Ticker Tape; Typewriter and QWERTY

Further Reading

Cortada, James W. 2000. *Before the Computer: IBM, NCR, Burroughs, & Remington Rand & the Industry They Created, 1865–1956*. Princeton, NJ: Princeton University Press.

Petroski, Henry. 1995. *The Evolution of Useful Things: How Everyday Artifacts—From Forks and Pins to*

Paper Clips and Zippers—Came to Be as They Are. New York: Vintage.

Ward, James. 2014. *The Perfection of the Paperclip: Curious Tales of Invention, Accidental Genius, and Stationery Obsession*. London: Profile.

Paper Bag

A version of the square- or flat-bottom paper bag in use today was invented in the 1800s by Margaret E. Knight (1838–1914). Knight rejected the notion that women ought to spend their lives in the home, instead devoting herself to developing inventions, an activity she had enjoyed for years. As a child, she worked in a textile factory, where she was fascinated with the mechanical looms and began devising methods for improving their safety. As a young adult, Knight took it upon herself to improve on the design of paper bags, which then lacked a square or “flat” bottom. Instead, early paper bags had “envelope bottoms” that could not be opened into a quadrangular shape and had to be held open while being filled. Knight successfully created and patented a machine for pressing square-bottom paper bags in 1871.

Today, square-bottom paper bags are widely used because they can stand up by themselves, allowing baggers to fill them quickly and efficiently.

Alberta M. Miranda

See also Roebling, Emily; *Vol. 2, Sec. 2*: Bryant, Alice; Dickerson, Mary Cynthia

Further Reading

Petrusso, Annette. 1999. “Margaret E. Knight.” In *Notable Women Scientists*, edited by Pamela Profitt, 52–53. Detroit: The Gale Group.

Stanley, Autumn. 1993. *Mothers and Daughters of Invention*. Metuchen, NJ: Scarecrow Press.

Paper Clip

The paper clip, a piece of bent wire used to hold papers together, arose with the explosion of commercial paperwork that accompanied the Industrial Revolution.

Paper clips come in many shapes, but the most common is the oval-within-an-oval design first manufactured by the Gem company.

Before the paper clip, sheets of paper were attached together using a method similar to binding a book: a pair of small slits was cut through the pages so they could be tied together with string or ribbon. In 1835, straight pins made of steel wire became widely available and were sold by the pound as “bank pins.” Pinning documents was more efficient, and its smaller holes were less damaging. However, pinning had several disadvantages. In addition to pricking workers’ fingers, repeated unpinning and repinning damaged the document corners, creating a floppy “dog ear.” The steel pins rusted during periods of prolonged storage and stained documents. The paper clip evolved as a reusable method of holding papers together while it protected both the documents and users’ fingers.

Johan Vaaler (1866–1910), a Norwegian inventor and patent clerk, is frequently cited as the inventor of the paper clip. He designed a single-loop paper clip in 1899 and was granted a U.S. patent on June 4, 1901. The patent described a clip made of “a spring material, such as a piece of wire, that is bent to a rectangular, triangular, or otherwise shaped hoop, the end parts of which wire piece form members or tongues lying side by side in contrary directions.” In addition to fastening papers, Vaaler’s invention became a unifying symbol in Norway during World War II, when Norwegians wore paper clips on their lapels as a sign of unification.

However, Vaaler was not the first to file such a patent. The U.S. Patent Office had on file approximately 50 designs for metal paper fasteners. The first patent for a bent wire paper clip had been awarded to Samuel B. Fay in 1867. The document stated that the clip was meant to attach papers to delicate fabrics, but it could also be used to attach papers together. The Fay paperclip was a single, triangular loop of wire, with two ends protruding from the apex. The Fay design was first produced by D. S. Gorman of New York in 1896 and marketed as the “Clinch Clip.”

Vaaler’s single-loop, rectangular paper clip has been confused with the double-loop, oval Gem paper clip in use today. In the 1870s, the Gem Manufacturing Company, Ltd began producing a functional paper clip that had two full loops of wire, one inside the

other. The Gem model was never patented, but there is evidence that it was developed before Vaaler’s 1899 patent application. The Gem paper clip was advertised in 1894.

In 1899, William D. Middlebrook was awarded a patent for a machine for manufacturing the Gem paperclip, and in 1904, Cushman and Denison registered a trademark for “Gem Paper Clips.” The announcement claimed that the Gem clips had been in use since March 1, 1892.

It is unknown who invented the Gem paper clip, but it remains the most popular paper fastener today. The original design met many of the criteria sought by office personnel: the double loops slid easily onto documents without mutilating the pages and prevented the clips from becoming tangled together in the box. The flat, thin wire wires made them inexpensive to purchase, took up less space in files, and required less postage to mail. Subsequent patents sought to improve upon the Gem by adding serrations to hold papers more securely, but the general design remains in use today.

Lynda C. Titterington

See also Office Technology (Pre–World War II)

Further Reading

Petrosky, H. 1992. *The Evolution of Useful Things: How Everyday Artifacts—From Forks and Pins to Paper Clips and Zippers—Came to Be as They Are*. New York: Albert H. Knopf.

Ward, J. 2014. *The Perfection of the Paper Clip: Curious Tales of Invention, Accidental Genius, and Stationery Obsession*. New York: Touchstone.

Phonograph

In 1877, Thomas Alva Edison (1847–1931) invented the phonograph, which was a way of recording and playing back sound for the first time. Phonograph technology had many practical uses. However, its entertainment value soon took center stage. In this regard, Edison, his team of assistants, and his competitors laid the foundation of the music-recording industry.



Thomas Edison, pictured here in 1878, invented the phonograph, or gramophone, in 1877. While other similar devices could record sound, Edison's was the first to reproduce sound. (Library of Congress)

Edison was not the first person to invent a machine for recording sound. In 1857, a Frenchman named Édouard-Léon Scott de Martinville invented a device that could record sounds by making visual images of sound waves. However, de Martinville's phonautograph (as he called it) could not play back the audio it captured. Other inventors had also created a method of representing sounds on punch cards that were used to program organs and for various other musical instructions.

Edison's work with sound began in the 1870s with his interest in recording telegraph signals. He devised a machine with a turning cylinder covered in wax and a needle that would vibrate and create impressions on the wax in response to telegraph signals. His experiment failed, because the machine was incapable of accurately discerning between the dots and the dashes. However, Edison noticed that the wax impressions generated an audible hum when he reversed the

procedure. He immediately realized that he had made an accidental breakthrough in sound playback.

In 1877, he and his lab assistants at Menlo Park, New Jersey, designed the prototype of what he called the phonograph (or sound recorder). The design of his new machine was almost identical to that of his previous one except that he replaced the wax paper with tinfoil, and he added a microphone. The sound quality was poor, but it successfully played back the first audible human voice: Edison's recitation of a nursery rhyme ("Mary Had a Little Lamb"). Edison, a veteran inventor, was amazed when he heard the recording of his voice for the first time. He filed for a patent for the phonograph in December 1877, and he received it two months later. With patent in hand, he established the Edison Speaking Phonograph Company (ESPC) as a way to profit from the new device.

Edison suggested several uses for his new invention. Among them were dictation, to save time in office work; audiobooks for the blind; elocution, a way to learn how to pronounce and articulate clearly; music recording, a way of listening to past performances; family record, a way to record sayings or reminiscences of family members in their own voices, including the last words of dying family members; as a music box or musical toy, as clocks that announced the time, such as when to go home or to go to lunch, in articulated speech; preservation of languages by recording them with exact pronunciation; educational purposes or recording a teacher's explanation of a certain subject so that a pupil could refer to the recording when and as many times as needed; for recording a teacher's correct spelling of words so that students could listen to it as many times as necessary and commit the correct spelling to memory; and connection to the telephone as a way of recording communications.

The immediate public reaction to Edison's device was overwhelming. Many amazed reporters descended on his lab for demonstrations. Many people who witnessed the invention and others who read about it compared it to magic. In fact, the popular press nicknamed him the "Wizard of Menlo Park." He was invited to Washington, D.C., to demonstrate the phonograph to the astounded President Rutherford B. Hayes and the U.S. Congress. As a way of creating a permanent

audiohistorical record, Edison asked famous people from his time to record messages on his phonograph. One of the participants was England's Queen Victoria. However, the novelty of Edison's phonograph prototype wore off quickly with the public.

By the 1880s, Edison paused his work with the phonograph to concentrate on designing and building power stations in New York to provide residents with electricity to power lightbulbs (the invention for which he is most remembered). Alexander Graham Bell (1847–1922), the inventor and patent holder of the telephone, decided to perfect Edison's phonograph technology. Edison's tinfoil phonograph design produced poor-quality audio. The cylinder could only record for about two minutes, and it deteriorated after two or three uses.

Bell set up a lab with assistants in Washington, D.C. He replaced Edison's hand crank system with a foot lever (or treadle) that imparted motion to the machine, and he replaced the tinfoil with a much more durable, wax-covered cardboard. Bell's changes and improvements in sound quality and durability garnered him a patent for his graphophone. However, Bell was still not satisfied with his progress, and he invited Edison to cooperate with him to create a better machine. Edison, who believed that Bell had pirated his phonograph technology, refused the invitation. Instead, in 1888, Edison responded competitively by creating a phonograph with better sound quality and a lower price than the graphophone.

In spite of the many uses that Edison had proposed for his new invention, public demand for it mostly centered around its entertainment value. In large cities, people would put coins in music penny arcades or pay a nickel to gather in phonograph parlors to listen to music or vaudeville comedy monologues. By the turn of the century, the ESPC was competing with several other companies for a fortune in pennies and nickels. One of the ESPC's biggest competitors was the Victor Talking Machine Company (VTMC) established in 1901 by Emil Berliner (1851–1929), the inventor of the gramophone.

The ESPC's phonograph cylinder had one major drawback: it could not be mass-produced. This meant that individual cylinders had to be recorded one at a time, with musicians repeating their performance for

each cylinder recording. The disadvantage of time-consuming cylinder recording limited the size of the catalog of music that the ESPC could offer. It also resulted in different recorded versions of the same songs. Edison made the catalog selections based on his own taste in music. In contrast, instead of cylinders, the VTMC used recorded discs made from hardened rubber, which could be mass-produced. One tremendous advantage of the use of discs was that the VTMC's catalog of music offered a much wider variety of artists.

While Edison was focused on the use of the phonograph in public places (as well as the public arena for the motion picture industry, which he pioneered), the VTMC introduced the first home entertainment system—the Victrola, which played discs and projected sound with a horn-shaped speaker. The Victrola cabinet was equipped with a compartment where records could be stored, and it looked like a piece of living room furniture. An added feature was the ability to retract (or hide) the horn speaker.

Edison responded by placing a cylinder (that could be mass-produced and could play four minutes of music) in a home hand-cranked phonograph he called the Amberola. Edison remained convinced that the best way to gain a lead in the phonograph market was by creating a machine that could produce the best sound quality. In 1912, due to popular demand, the ESPC replaced the cylinders with discs. By 1915, the Amberola's fidelity was superior to all other home systems on the market. In advertisements, Edison boasted about the superiority of his discs by claiming that they could be played 1,000 times without wear. In spite of these improvements, the Victrola remained the more popular machine for several reasons.

Most important, the VTMC still offered a much larger record catalog. Also, most consumers found the Edison record cabinet less attractive than the Victrola's. In the past, Edison had been able to control his catalog sales by offering only cylinders while his major competitor sold discs. However, once Edison dispensed with the cylinders and adopted discs, he designed discs that would play only on Edison phonographs. Many consumers did not like the restriction. In the 1920s, static filled radio broadcasts, and home

radio sets became extremely popular. Edison believed it to be a passing fad. He was wrong. While the VTMC survived the radio craze, the ESPC did not: it went out of business in 1929.

Although Edison did not triumph in his phonograph competition, he was responsible for creating the primitive technology that greatly contributed to the birth of the music industry. In later years, various types of electronic phonographs were known generically as “record players” (or turntables). As early as the 1930s, exclusive record catalogs became obsolete when numerous record companies and record shops were established. More people than ever before were listening to music (and a greater variety of it).

After World War II (1939–1945), millions of American children (baby boomers) were born between 1946 and 1964. There were so many of them that people started calling them “teenagers.” Due to the affluence of the 1950s, many parents gave their children allowances—regularly supplied spending money. Teenagers, whose lives revolved around the music culture, viewed television programs, like *American Bandstand* (which featured teenagers showing off their latest dance steps), and then they rushed to their local shops to buy records with the latest songs that they then played and danced to at home. The demand for records led to many innovations in the booming record industry, including the creation of the long-playing (LP) record that included approximately 12 songs (6 on each side).

The demand also created an opportunity for new artists like the Hispanic Ritchie Valence; African Americans including Chuck Berry, Little Richard, and Ray Charles; and poor Southern whites, including Buddy Holly and Elvis Presley. The *Elvis’ Christmas Album* (1957) LP became the biggest seller of the 1950s, selling more than 7 million copies. The biggest-selling record of the 1960s was the double LP *The Beatles* (a.k.a. “The White Album”) (1968), selling more than 19 million copies. Record sales continued to rise in the 1970s and 1980s. Michael Jackson’s *Thriller* (1982) LP sold more than 30 million copies.

Although music remained a group experience with concerts and dances, home record players also made music a personal experience that one person could

enjoy alone. Unlike spontaneous live performances that often changed, records froze (or standardized) performances so that they could be heard exactly the same way each time the record was played. This allowed aspiring musicians or singers to play songs over and over until they learned them. This also changed many live performances, because audiences who were familiar with artists’ recorded work expected to hear the songs performed exactly the same way in a live setting.

Long after Edison’s death, all of the suggested uses that he proposed for his invention were realized: the use of recordings to facilitate office work, the creation of audiobooks, music boxes, musical toys, family diaries, talking clocks, educational recordings, answering machines, and music recording. Edison did not foresee that the entertainment value of the phonograph would be the greatest determinant in generating consumer interest. But, once he recognized this phenomenon, he attempted to capitalize on it. There were also some applications of his invention that he did not originally foresee. For example, by the late 1920s, motion pictures, which had been silent for years, benefited from the addition of recorded sound. Like Edison, others embraced the quest for a more perfect sound. These endeavors led to important developments, including stereo sound (distinct sounds directed through two or more speakers) in 1957 and digital music recorded on compact discs (CDs) in 1982.

Rolando Avila

See also Bell, Alexander Graham; Edison, Thomas; *Vol. 1, Sec. 3: Telegraph; Vol. 2, Sec. 3: Telephone*

Further Reading

- Butler, Rebecca P. 2012. “Thomas Edison Speculates on the Uses of the Phonograph.” *TechTrends* 56, no. 4 (July/August): 8.
- Gelatt, Roland. 1977. *The Fabulous Phonograph, 1877–1977*. New York: Macmillan.
- Millard, Andre. J. 2005. *America on Record: A History of Recorded Sound*. 2nd ed. New York: Cambridge University Press.
- Read, Oliver, and Walter L. Welch. 1976. *From Tin Foil to Stereo: Evolution of the Phonograph*. Indianapolis: Howard W. Sams.

Primary Document: Roll Call of Companies at the Phonograph Convention in Chicago (1890)

In 1890, the Phonograph Convention met in Chicago, Illinois, at the Auditorium Hotel. The following is a roll call of the companies represented at the convention. Note the diversity of geographic location, which suggests that the popularity of phonographs extended well beyond the large urban centers on the two coasts.

PHONOGRAPH CONVENTION. AUDITORIUM HOTEL, CHICAGO, ILL., May 28, 1890.

MORNING SESSION.

The chairman then appointed as committee on permanent organization, Messrs. Easton, Gottschalk and Stone. Motion for roll call was then unanimously adopted and the roll was thereupon called as follows:

The Alabama Phonograph Co., Anniston, Alabama; Mr. Chas. A. Cheever, President.

The Central Nebraska Phonograph Co., Kearney, Nebraska; E. A. Benson, Director.

Chicago Central Phonograph Co., 801 and 804 Home Insurance Building, Chicago, Ill.; Geo. B. Hoit, General Manager, E. A. Benson, Chas. Dickinson, Directors.

The Columbia Phonograph Co., 627 E Street, N. W., Washington, D. C.; E. D. Easton, President, R. F. Cromelin, Secretary, W. H. Smith, Treasurer.

The Colorado and Utah Phonograph Co., Denver, Colorado; S. W. Cantril, Manager, John Barber, Assistant Manager.

The Eastern Pennsylvania Phonograph Co., 130 South Fourth St., Philadelphia, Pa.; Jas. O. Clephane, Secretary.

The Florida Phonograph Co., Jacksonville, Fla.; J. C. Clarkson, Superintendent.

The Georgia Phonograph Co., 43 Walton St., Atlanta, Ga.; J. C. Clarkson, Superintendent.

The Iowa Phonograph Co., Sioux City, Iowa; Whitfield Stinson, Secretary.

The Kansas Phonograph Co., Topeka, Kan.; Geo. E. Tewkesbury, President. The Kentucky Phonograph Co., Louisville, Ky.

The Metropolitan Phonograph Co., 257 Fifth Avenue, New York City, N. Y.; Chas. A. Cheever, President, Felix Gottschalk, Secretary.

The Michigan Phonograph Co., 15 & 17 Detroit Opera House, Detroit, Michigan; W. H. Freeman, Manager, C. W. Swift, Secretary.

The Minnesota Phonograph Co., 108 Rochester Block, Minneapolis, Minn.; C. H. Chadbourne, General Manager. A5 Missouri Phonograph Co., 416 3rd Avenue, South, Minneapolis, Minn.; J. C. Wood, W. J. Wood, Geo. L. Wood, A. W. Clancy, Vice-President, J. C. Elliot, General Manager. The Montana Phonograph Co., Helena, Montana; E. A. Benson, Director. The Nebraska Phonograph Co., Omaha, Nebraska; E. A. Benson, President. The New England Phonograph Co., Boylston Building, Boston, Mass.; A. N. Sampson, Manager. The New Jersey Phonograph Co., 758 Broad Street, Newark, N. J.; W. L. Smith, General Manager. The New York Phonograph Co., 257 Fifth Avenue, New York City, N. Y.; John P. Haines, President.

The Ohio Phonograph Co., 220 Walnut Street, Cincinnati, Ohio; Jas. L. Andem, President.

The Old Dominion Phonograph Co., Masonic Temple, Rooms 8 and 9, Roanoke, Va.; J. H. McGilvra, President. The Pacific Phonograph Co., 323 Pine Street, San Francisco, Cal.; Louis Glass, General Manager.

The South Dakota Phonograph Co., Sioux Falls, Dakota; Henry Lacey, General Manager.

The Spokane Phonograph Co., Spokane Falls, Washington; Louis Glass, Director. State Phonograph Company of Illinois, 804 Home Insurance Building, Chicago, Ill.; G. Farwell, W. H. Hubbard and Ed. Lobdell, Directors.

The Texas Phonograph Co., Galveston, Texas; H. L. Sellers, President, Thos. Conyngton, General Manager.

The West Coast Phonograph Co., Portland, Oregon; Louis Glass, Director.

The Western Pa. Phonograph Co., 146 Fifth Avenue, Pittsburgh, Pa.; J. H. Friend, Secretary.

The Wisconsin Phonograph Co., 414 Broadway, Milwaukee, Wis.; Henry D. Goodwin, Secretary; W. S. Burnett, Superintendent.

The Wyoming Phonograph Co., Cheyenne, Wyoming; E. L. Lindsay, Manager

Source: *Proceedings of the First Annual Convention of Local Phonograph Companies of the United States Held at Chicago, May 28 and 29, 1890.* Milwaukee: Phonograph Printing Company, 1890.

Photographic Film

Photography began with the usage of heavy, wet plates that captured images of subjects and that required processing to fully develop the images. These wet plates paved the way for the creation of photographic film through experiments with chemicals that later helped refine the images' resolution. Photographic film is a plastic strip coated with gelatin emulsion, a chemical creation invented by Richard Leach Maddox. The gelatin emulsion determines the sensitivity, contrast, and resolution of the film depending on the size and characteristics of the light-sensitive halide crystals embedded in it. Louis Daguerre, a French painter and inventor, created the earliest photographic process, and it influenced the American photography industry.

In 1939, Daguerre introduced his photography technique, which became known as "daguerreotype." It did not use film but used liquid iodine as the light-chemical reactive and copper plate as the base for photographs. The daguerreotype was cumbersome to use due to the heavy plates and the box-type camera, but the invention was revolutionary and was adopted worldwide. Mathew Brady, an American photographer, recognized as the "father of journalism," learned the daguerreotype process from Samuel F. B. Morse, an American inventor famous for his work on the telegraph.

Brady photographed historical figures such as Abraham Lincoln and Robert E. Lee, but most important, he captured real-life moments on the battlefields of the Civil War (1861–1865). His process consisted of planting the camera, focusing the lens, coating the plate, and developing the image while it was still wet. Although it was an arduous process, his images have great historical value; they exposed the never-before-seen truths of this gruesome war. The thin glass plates were coated with photographic emulsion; this provided better optical quality but did not solve the problem of carrying bulky plates. It was not until 1885 that the United States was introduced to the first flexible photographic roll film.

Born on July 12, 1854, American entrepreneur George Eastman founded the Kodak Company, which introduced the new innovation of roll film in May 1885.

Eastman's first film was composed of an image-bearing layer attached to a sheet of hardened, clear gelatin. Four years later, Eastman improved the photographic roll film by utilizing nitrocellulose ("celluloid"), a flammable compound now termed "nitrate film," to introduce his newly refined transparent plastic roll film. Although the nitrate film was hazardous, it had the advantages of being durable, slightly more transparent, and cheap. This was a huge development that encouraged many to explore photography.

Eastman utilized an early photographic process called "calotype," invented by Henry Talbot, and gelatinous silver nitrate plates, invented by Richard Maddox. He provided consumers with a simple box camera and a 100-exposure roll of film. Once all the exposures on the film were completed, the consumer would send the entire camera to the factory in Rochester, New York, and wait until the camera was sent back with a reload of film. Meanwhile, the first film was at the factory to be developed. The greatest advantage of this camera was its simplicity. Kodak's advertising slogan was "You press the button, we do the rest." Although the camera was introduced at a high price of \$25, it mainly attracted amateurs who were excited to capture spontaneous moments with a series of pictures. In 1900, the Brownie camera was introduced, this time at the low price of \$1. Eight years later, Kodak introduced cellulose acetate, also known as safety film, for usage in 16-mm and 8-mm home movies as well as for x-ray film.

As photographic film improved, instant photography gained popularity. The camera and film no longer required additional chemicals or equipment. Instant film was introduced by Polaroid. Film maintained its popularity until the 21st century, when digital cameras became accessible to consumers. The first digital camera was released in 1989 as the Fuji DS-X. This innovation also promoted the development of photography software and color printers. Film has not been completely abolished; it continues to be used by photography enthusiasts who prefer the unique look that a film photograph has.

Nicole Quintero

See also Eastman, George; *Vol. 1, Sec. 3*: Morse, Samuel F. B.; Telegraph

Further Reading

- Dickson, W. K. L., and Antonia Dickson. 1895. *History of the Kinetograph, Kinetoscope and Kinetograph*. New York: Museum of Modern Art.
- Ford, Colin, and Karl Steinorth. 1988. *You Press the Button, We Do the Rest: The Birth of Snapshot Photography*. London: D. Nishen.
- Kadiyali, Vrinda. 1996. "Entry, Its Deterrence, and Its Accommodation: A Study of the U.S. Photographic Film Industry." *Rand Journal of Economics* (Autumn): 452–78.

Pipe Wrench

A pipe wrench is a tool with an adjustable jaw that allows it to lock onto the pipe being repaired; any forward pressure on the handle pulls the jaws together. Solymon Merrick, an American entrepreneur, patented the first wrench, originally called the "spanner," in 1835. As the wrench continued to progress through small innovative ideas, Daniel C. Stillson, a steamboat engineer and American inventor, patented the pipe wrench in September 1870. Stillson reached out to Walworth Company to put it into production, but he had to design a working prototype first. The pipe wrench user aims to maintain a firm grasp on the pipe without jerking the wrench, as the handle can either tighten or loosen it. Stillson's tests of the wrench proved to be successful, and the production of the pipe wrench commenced.

Stillson worked as a cotton picker in New Hampshire before the Civil War. During the war, he was offered a position as an acting third assistant engineer for the navy. He worked his way up to acting first assistant engineer. After leaving the navy, Stillson moved to Mississippi to live with his family and worked for the Walworth Company. Around this time, he and his cousin applied for U.S. patent number 50,748 for the pipe wrench. After some improvements, they received U.S. patent number 95,744. Initially, the cousins were going to sell their invention for only \$2,500, but their employer advised them not to. At the time, Stillson believed that \$2,500 up front was a better deal than royalties, but over his lifetime, he received about \$80,000.

The wrench had one swivel jaw to prevent it from loosening as its handle was turned. It also included a screw knob, used as a security measure to maintain a lock on the bolt or pipe. It could adjust to any size of bolt. With enough pressure and torque, the wrench was capable of a full 360-degree rotation. During production, the Walworth Company credited Stillson by engraving his name on the wrench. The Stillson pipe wrench became a fast-selling commodity, and in 1905, other companies made "Stillson" and "Stillson pattern" wrenches shortly after his patent expired. These wrenches usually included minor changes to their material, size, and handle design.

Daniel Stillson revolutionized the way people work in factories, since the pipe wrench made it easier for laborers to loosen and tighten bolts.

Nicole Quintero

See also *Vol. 1, Sec. 3: Ratchet Wrench*

Further Reading

- Mital, A. 1998. "Effect of Body Posture and Common Hand Tools on Peak Torque Exertion Capabilities." *Applied Ergonomics* 55, no. 2: 309–22.
- Stillson, D. C. 1869. Improvement in Pipe Wrenches. U.S. Patent 95,744, filed September 11, 1869, and issued October 12, 1869.
- Usdin, Tommie, and Tony Graham. 1998. "XML: Not a Silver Bullet, but a Great Wrench." *Bibliometrics* 6, no. 3: 125–32.

Player Piano

The player piano is a self-playing piano. It was popular during the late 19th and early 20th centuries. It peaked in popularity 1924 and then went into a sharp decline due to improvements in phonograph recording.

Henri Fourneaux invented what he called a "Pianista" in 1863. Fourneaux's piano was the first with a pneumatic mechanism and it was introduced at the Philadelphia Centennial Exhibition in 1876. Several American inventors contributed to the player piano's evolution, including John McTammany, Frank Van Dusen, and Henry and William Schmoele.

In 1910, the player piano was advertised in a highly profitable campaign that used a full-page color advertisement that cost \$250, which in 2016 is equivalent to \$7,200. By the 1920s, the piano player had reached its peak. In the United States, perhaps more than half of all pianos made were player pianos.

Player pianos come in several types. Most are “split stack control” instruments, meaning that operating mechanisms can be found both above and below the keyboard. Many split stacks allow operators to change volume on all or part of the keyboard. “Theme control” instruments have pneumatic systems that allow part of the score on a roll to be emphasized over other parts. “Isolated theme” pianos pick out particular melody notes, while “reproducing” player pianos are fully automated. These last are the type most often thought of as player pianos. Fully automated, or reproducing, pianos require no human interaction. Instead, a roll is inserted into the instrument, and an operator turns it on, allowing the piano to play a piece of music independently of human hands.

Related to the player piano is the orchestrion, which combines piano, organ, percussion, and other instruments. Orchestrions were generally used in commercial settings such as fairs, circuses, and music halls. They were replaced by the more versatile, smaller, and more affordable jukebox by the mid-20th century.

Musical rolls for player pianos include the hand-played roll and the word roll. The hand-played roll added musical phrasing to the musical roll so that pianists had some help with tempo. Word rolls included the words to songs, usually printed in the margins of the roll.

It was not until October 1929 and the Wall Street crash that the piano player started its sharp decline. Between the 1930s and 1950s, many player piano companies closed their doors and their factories. Some of the final rolls for player pianos were issued in the late 1930s. By 1940, many factories had stopped making new classical rolls. In the 1950s, many collectors started to rescue player pianos, and in the late 20th and early 21st century, there was a small revival in them, particularly in their reconstruction and reproduction.

Alicia L. Garcia

See also Phonograph; *Vol. 1, Sec. 1*: Glass Harmonica (Armonica); *Vol. 1, Sec. 2*: Banjo Clock; *Vol. 2, Sec. 3*: Electric Guitar; FM Radio

Further Reading

Grew, Sydney. 1925. *The Player-Piano*. Oxford: Oxford University Press.

Roehl, Harvey. 1961. *Player Piano Treasury: The Scrapbook History of the Mechanical Piano in America, as Told in Story, Pictures, Trade Journal Articles and Advertising*. Salt Lake City: Vestal Press.

Vonnegut, Kurt. 1999. *Player Piano: A Novel*. New York City: The Dial Press.

Portland Cement Mortar

Portland cement mortar, an adhesive that adheres bricks together to create structures, was created and patented on October 21, 1824 by Joseph Aspdin, a British cement manufacturer from Leeds. It is called Portland cement because of its similar appearance to a limestone quarried on the Isle of Portland in England. The cement revolutionized engineering and architecture around the world. Although the product originated in England, the rest of the world mimicked and improved on Aspdin’s invention in the century after its creation.

Aspdin experimented with different substances and mixtures to produce a cement that would outperform other cement-like products in every critical category. Portland cement is created with crushed limestone put into one entry of a kiln while coal dust is added through another entry. High temperatures help infuse the coal dust into the ground limestone to create lumps that are put into containers and immediately exposed to steam. The lumps go through a grinder a second time to further pulverize them and create the distinctive, gray powdered cement we see today.

The United States was falling behind in the cement-manufacturing business, manufacturing “natural” cement. Portland cement took over the market, and it was adopted in the United States. Experiments done in the United States to improve on the product eventually put American cement at the top of the

international cement market. The Portland Cement Association was created to research and continue experimentation.

With the growing improvements in and understanding of cement, as U.S. industry expanded, the perfect moment for Portland cement was its use in creating new U.S. infrastructure. Prior to the 1920s, roads and pavements were made up of less than 1.5 percent cement, but the amount grew to 20 percent, and the new cement was used frequently in the construction of other institutions such as schools and hospitals.

Portland cement turned out to be cost-efficient while maintaining its strength and versatility. Without Portland cement, our highways, roads, and sidewalks would all be less stable. Portland cement was a great factor in the growth of U.S. industry as cities expanded around highways and roads, and it allowed the entire country to become connected.

Jordan Joya

See also Asphalt; *Vol. 1, Sec. 2: National Road*

Further Reading

Abrams, Duff A. 1925. "The Contribution of Scientific Research to the Development of the Portland Cement Industry in the United States." *The Annals of the American Academy of Political and Social Science* 119: 40–47. www.jstor.org/stable/1015405, accessed August 29, 2018.

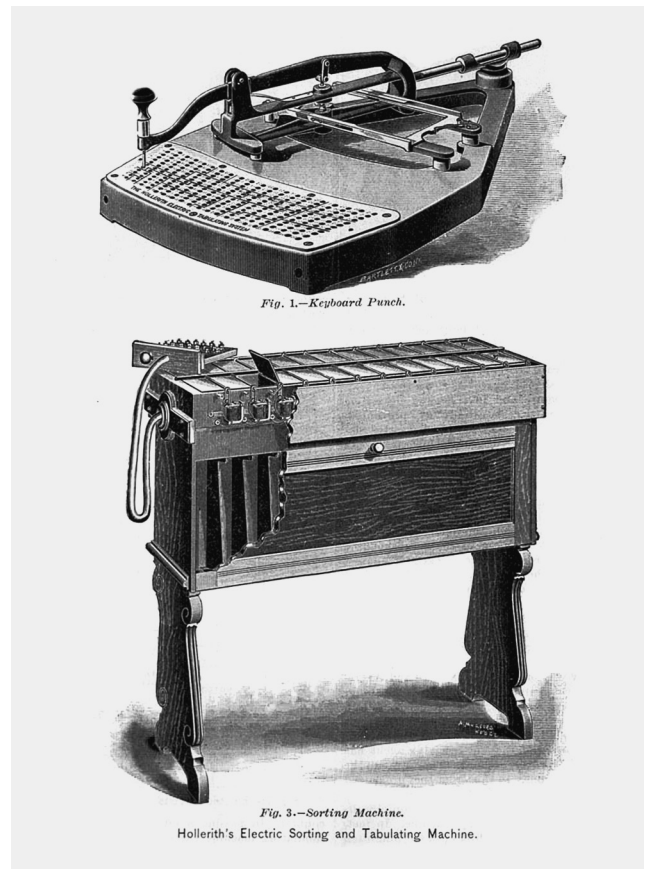
Davis, A. C. 1911. "The Manufacture of Portland Cement." *Journal of the Royal Society of Arts* 59, no. 3044: 479–91. www.jstor.org/stable/41339597, accessed August 29, 2018.

Winship, A. E. 1927. "What America Owes to Portland Cement." *The Journal of Education* 106, no. 22: 584–85. www.jstor.org/stable/42835098, accessed August 29, 2018.

Pullman Car. See Railroad Sleeping Car and Pullman Car

Punch Card Tabulator

Prior to the creation of the punch card tabulator, the United States had the tedious task of handwriting the U.S. census. During the 1880 U.S. census, clerks



Herman Hollerith built the first punch card tabulating machine in the late 1880s. The 1890 census took only one year to tabulate using this machine, compared to the eight years it took to count the 1880 census. (Library of Congress)

employed by the Census Bureau took years to compile and record all the census information. This was one result of an influx of immigration along with a population boom. Realizing that this method was inefficient and costly, some within the bureau proposed an invention that could record the information efficiently. Herman Hollerith, a clerk working in the bureau, was the eventual inventor of the punch card tabulator, patenting it under the title "Art of Compiling Statistics" on January 8, 1889.

Although punch cards were already in use by train clerks, Hollerith wanted to create a machine that could both assemble and store data. His machine had three different sections. The first section, the "press," read the data from the cards. The second was "the counter," and last was the "sorting box."

To organize the information the machine gathered, Hollerith began with a "templet," or pattern, that listed

the name or characteristic of an individual in a certain order. The templet contained several categories of individual characteristics, such as a person's age, country of origin, gender, etc. The templet had 288 holes available to be punched. The second step was to collect and compile all the characteristics of an individual on a strip of paper. The person would place this strip, or "tablet," into the machine. The data recorded on the strip would then be transferred onto the punch card tabulator. As the paper ran through the machine, the data was recorded based on the holes punched. This is done by having "circuit-controlling index-points" in "a fixed relation to each other." To put it simply, the paper or templet acted as a barrier between the index points. When the paper passed through the machine, wherever there was a hole punched in the paper, an electrical circuit registered as a result of an "opening" in the barrier, which caused the index points to close the circuit.

The third and final step was to transfer the stored information transferred onto a new templet. Based on corresponding numbers from the initial recording, the machine registered the characteristics of the individual. The system could store population information for the U.S. Census as well as registrations of any kind, such as births, deaths, and marriages. This Hollerith's "counting-machine" was built of a metallic drum with pointers or pins that were insulated and required electricity to function.

Once the punch card tabulator was approved by the patent office, however, the Census Bureau became a bit hesitant to use it for the 1880 census, as it believed that the machine would interfere with all the work they had already completed. In the end, it decided to take the risk and test the tabulator. Hollerith's invention helped the Census Bureau to improve its operations by saving time and money while improving statistics keeping. Hollerith was rewarded for his amazing invention: the Franklin Institute of Philadelphia awarded him the Elliot Cresson Medal for his success. The punch card tabulator is considered one of the first "modern" computing systems.

Jordan Joya

See also Adding Machine with Keys; *Vol. 3, Sec. 2: CD-ROM*

Further Reading

- Heide, Lars. 1997. "Shaping a Technology: American Punched Card Systems 1880–1914." *IEEE Annals of the History of Computing* 19, no. 4: 28–41.
- Hollerith, Herman. 1889. Methods or arrangements for sensing record carriers, e.g., for reading patterns by mechanical means, e.g., by pins operating electric contacts. U.S. Patent 395,782, issued January 8, 1889.
- Kistermann, Friedrich W. 2005. "Hollerith Punched Card System Development (1905–1913)." *IEEE Annals of the History of Computing* 27, no. 1: 56–66.

Quadruplex Telegraph

In 1874, Thomas Edison created one of his most important telegraph inventions ever, the quadruplex telegraph—which could send four telegraph signals at the same time. This was much more efficient than its predecessors, the duplex and diplex, which were only capable of sending two signals at a time. Edison was actually instructed by Western Union to invent a more efficient telegraphic machine to save the company money in the future.

Edison had made enough of a name for himself that Western Union desired his skills in telegraphy. Western Union invested in buying out as many telegraph patents as possible to have advantage over its competition. It made sense for both sides to work with each other, as Edison had for years worked on solving the puzzle of sending two messages over one wire at the same time. Edison was given resources from Western Union to experiment on the issue while the company reaped the benefits by owning the rights to the quadruplex telegraph.

As Edison began work on an efficient telegraphic machine, he experimented with previous telegraphs such as the duplex and diplex. He soon discovered that incorporating the duplex and diplex with each other, he could send four messages concurrently on one wire. To do this, Edison employed an ingenious method that he had used in prior telegraphic projects. He created a polarized relay to react to any shifts in polarity from a current while the other "normal" relay reacted to the

strength of the current. This allowed for the relays not to overload or be placed in a difficult situation to react to either the strength of a current or its polarity. Once Edison solved this problem, he introduced the invention to Western Union, which paid him \$10,000 for it. The quadruplex telegraph had become his most lucrative invention.

Edison's invention allowed telegraph companies like Western Union a wide range of opportunities. Many messages sent over a single line lowered the time in which messages were received or sent and meant less traffic on the wires. Messages with different topics could even be sent simultaneously to a recipient, who no longer had to wait to receive the next message. The quadruplex telegraph benefited everyone by making communication simpler. Important or urgent messages could be sent faster and to more people. Telegraph companies had more lines available for other uses, so they began renting or leasing their lines to interested customers.

Even though he had signed a contract, Edison sold his patent rights to a Jay Gould prior to the offer given by Western Union. This led to a court battle between Gould and Western Union over the rights. Both sides knew how important the quadruplex telegraph would be. The courts ruled in favor of Western Union, as it had a signed contract. The invention saved Western Union tremendous amounts of money and allowed it to keep up with the growing popularity of sending messages.

Jordan Joya

See also American Telephone and Telegraph Company (AT&T); Edison, Thomas; *Vol. 1, Sec. 3: Western Union Telegraph Company*

Further Reading

Hochfelder, David. 2012. *Johns Hopkins Studies in the History of Technology: The Telegraph in America, 1832–1920*. Baltimore: Johns Hopkins University Press.

“Thomas A. Edison Papers.” Quadruplex—The Edison Papers. <http://edison.rutgers.edu/quad.htm>, accessed August 29, 2018.

Wheeler, Everett P. 1927. “The Telegraph Cases.” *American Bar Association Journal* 13, no. 7:

410–15. www.jstor.org/stable/25707200, accessed August 29, 2018.

QWERTY Layout. See Typewriter and QWERTY

Railroad Refrigerator Car

The first U.S. patent for a refrigerated railcar was granted to John Buie Sutherland (1825–1895) of Detroit, Michigan, on November 26, 1867. Gustavus Swift (1839–1903) improved on Sutherland's design, and the Swift-Chase refrigerated car became the industry standard for decades. Mechanically cooled cars, as opposed to ice-cooled cars, were developed in the 1950s.

As demand for beef rose among consumers in the major urban markets of the United States, meatpackers sought ways to centralize and economize meat processing. Railroad cars had long been used for shipping live cattle, but there were many inefficiencies involved in this practice—the cattle lost weight during long trips and had to be watered and fed at stops along the way. Also, 60 percent of the weight of a live animal represented waste or inedible by-products.

John Sutherland, an immigrant from Scotland, was a master car builder for the Michigan Central Railroad. He knew that ice had been used to cool shipments of milk, butter, poultry, and seafood since the 1840s. On that principle, Sutherland developed a car with ice bunkers at each end and vents in the floor that helped the air to circulate. A significant limitation of his design, however, was the fact that the car could only be reiced when empty. Sutherland could not find investors willing to back his plans to build the cars, so little came of his patented design.

Another Detroit resident, William Davis, built a car with some improvements on Sutherland's design in 1868, and meatpacker George H. Hammond used it. Hammond built a major meatpacking plant in northern Indiana and founded the city of Hammond in the process. In the early 1880s, Hammond had 800 refrigerated cars in service and was processing 100,000 head of cattle per year.

Gustavus Swift was in the meat business in New England and sought more efficient ways to transport

meat from the vast stockyards of Chicago to Boston and other Eastern cities. In 1878, he hired a Boston engineer named Andrew Chase to design a refrigerated car. Chase's car was a considerable improvement over previous designs. It was well insulated, had ice bunkers near the roof of the car that could be replenished from the outside while the car was loaded, and had a forced-air ventilation system to keep the cold air circulating around the meat.

Nonetheless, most railroads, which had already made huge investments in stock cars for shipping live cattle, showed little interest in the refrigerator car. Swift mortgaged most of his own property to get the first of his cars built by the Michigan Car Company in 1879. This design, known as the Swift-Chase car, became the standard refrigerated rail car in the United States until well into the 20th century. Because railroads in the eastern part of the country were reluctant to haul his cars, Swift made a deal with a Canadian railroad, the Grand Trunk Line, to move his cars through Canada to the eastern U.S. markets. By 1880, Swift had more than 200 cars in service and was shipping 3,000 beef carcasses from Chicago to the East Coast weekly. Because the ice in the cars had to be replenished along the way, facilities had to be built for making ice and for packing the ice into the cars. Swift estimated that an equal amount of ice was needed for the weight of the beef being shipped. Even with this expense, however, he could ship three dressed beef carcasses for the cost of shipping one live animal.

As the railroads eventually embraced the new technology, many other meatpacking companies built their own fleets of "reefer" cars, and refrigerated cars were also used in shipping fresh vegetables and fruits. Many railroads created subsidiary companies to operate their own fleets of refrigerated cars. In the 1950s, cars equipped with mechanical refrigeration units began to replace the ice-cooled cars, but about the same time, similar technology was invented for trucks, and the trucking industry began to capture most of the movement of refrigerated cargoes.

Mark S. Joy

See also Railroad Sleeping Car and Pullman Car; *Vol. 1, Sec. 3: Railroads*

Further Reading

Skaggs, Jimmy M. 1986. *Prime Cut: Livestock Raising and Meatpacking in the United States, 1607–1983*. College Station: Texas A&M University Press.

Railroad Sleeping Car and Pullman Car

Though popularized by George M. Pullman (1831–1897), the railroad sleeping car predates Pullman's cars by 20 years. Pullman designed the most widely used cars and created the system of contracting with the major American railroads to operate his sleeping cars and dining cars on their lines. By the early 20th century, he had a virtual monopoly on the sleeping car business in the United States, and the name "Pullman" had become synonymous with quality sleeping car service.

Several eastern railroads were offering sleeping car service in crudely designed cars by the 1830s and 1840s. Generally, customers found these cars cramped, dirty, and poorly ventilated. Most simply had bunks built along their sides, which were useful only for sleeping, and the passengers would ride in other seats during the daytime. A key element in the design of Pullman's cars was convertibility—the cars could be used as chair cars in the daytime, and the same seats were converted into sleeping berths for nighttime travel, with an additional overhead berth. Over time, the Pullman firm designed many different styles of sleeping cars with different levels of comfort and privacy that could be offered to the traveling public at various fares—but the backbone of the Pullman fleet was the open-section sleeper, a car with 12 sections with an upper and lower berth in each section. Pullman staffed these cars with porters who were hired from among freed African American slaves; he believed that former slaves who had been house servants would know how to give professional service to passengers.

Pullman was born in Albion, New York, in 1831. He worked with his father as a carpenter and in moving houses. In 1855, he moved to Chicago and gained a reputation as an expert in raising buildings to meet new street levels. In 1858, he contracted with the Chicago and Alton Railroad to convert three day coaches into

sleeping cars. Although these cars were well received by customers, the railroad did not order any more conversions. After spending some time in Colorado during a mining rush there, Pullman returned to Chicago and convinced the Chicago and Alton Railroad to allow him to build a completely new sleeping car rather than making conversions as he had previously.

In 1865, he built the Pioneer—a large, elegant car to provide comfortable sleeping arrangements for travelers. The car was wider and taller than normal railroad equipment and might never have been adopted as a standard were it not for the favorable publicity Pullman received when the car was used in President Abraham Lincoln’s funeral train. The Lincoln family rode in the car during the trip from Washington, D.C., to Springfield, Illinois, in 1865.

Pullman raised \$1 million in capital by selling by selling stock to railroad executives and industrialists. The Pullman Palace Car Company was incorporated in Illinois in 1867. Pullman patented some of his designs for sleeping and dining cars in 1869, and he bought the Detroit Car and Manufacturing Company to use as a plant for building his cars. In 1880, Pullman built a new factory and the town of Pullman on a 4,000-acre site south of Chicago.

Over time, Pullman bought many competing companies, and in 1889, his purchase of the Wagner Palace Car Company, which had been building sleeping cars for the New York Central Railroad and other eastern lines controlled by the Vanderbilt family, was a major step toward control of virtually all the sleeping and dining car business on American railroads. By 1910, all of Pullman’s competitors had either been merged into his company or gone out of business. Besides sleeping and dining cars, the Pullman Company also built mail cars, refrigerated cars, streetcars, and a variety of freight cars.

The key to Pullman’s success was providing high-quality service, plus the fact that he operated the sleeping and dining cars for the railroads rather than simply building and selling the cars. He called this means of doing business the “Pullman system.”

Mark S. Joy

See also *Vol. 1, Sec. 3: Pullman, George Mortimer; Railroads*

Further Reading

Douglas, George H. 1992. *All Aboard: The Railroad in American Life*. New York: Paragon House.

Leyendecker, Liston E. 1992. *Palace Car Prince: A Biography of George Mortimer Pullman*. Niwot: University Press of Colorado.

Railroad Switch Systems

A railroad switch, also called a signal switch, is a mechanical system that allows trains to change tracks. Charles Fox patented the first such switch in 1832.

Fox used a system of rods and levers for a signal box that would direct the movement of the trains by use of sliding rails. Fox used a stub switch, or the blunt ends of railroad tracks (track ends lacking the now-common tapered ends found at switching conjunctions). This switch system was not suitable for high speeds, so trains had to slow down to switch tracks. Stub switches are also monodirectional: trains can go only one way on the switch, and a reversal of direction would cause a derailment.

After the Civil War, George Westinghouse recognized the need for better signaling devices once the development of rail yards increased, and that is when he developed the interlocking switches. The very first searchlight signal was created in 1869 by Thomas Hall and produced by the Hall Signal Company. By acquiring this company, Union Switch and Signal was able to produce its own searchlight models based on Thomas Halls’ invention.

In 1881, George Westinghouse combined the Union Electric Signal Company and the Interlocking Switch and Signal Company to make Union Switch and Signal (US&S). This allowed Westinghouse to take advantage of track circuits and interlocking. Interlocking uses a number of signals to prevent dangerous and conflicting movements on the tracks and is designed so that the display of a signal is impossible unless a certain route is proven clear and safe. Eventually, US&S was able to procure the Hall Signal Company that allowed them to own the patents for searchlight signals.

In 1882, the very first power interlocking system was created in the United States by US&S, and 30

years later, it developed an electropneumatic system that used electricity, pneumatic pressure, and hydraulic pressure. The pneumatic pressure set the safety signals and threw switches; electricity ran the valves that regulated the signals, and hydraulic pressure activated the valves that regulated the switches. Failures could occur within this system, though, and they were only noticeable when there was an attempt to change a control element's setting.

Today's railroad switch systems are powered by electricity and are managed by electronics. Turnout speeds, the speed at which a train might take a track switch, have increased dramatically, with some modern switching systems able to allow speeds up to 80 miles per hour.

Goo Conejos

See also Westinghouse Air Brake; *Vol. 1, Sec. 3: Railroads*

Further Reading

Hughes, Murray. 2015. *The Second Age of Rail: A History of High Speed Trains*. Charleston, SC: The History Press.

Skrabec, Quentin R. 2006. *George Westinghouse: Gentle Genius*. n.p.: Algora.

Richards, Ellen Swallow (1842–1911)

The “First Lady of American Science,” Ellen Swallow Richards, founded the science of ecology as well as the study of home economics. The first woman to graduate from the Massachusetts Institute of Technology (MIT) in chemistry, Richards was concerned with the growing pollution associated with the industrial age in America. Her work set standards for clean air, pure water, and an uncontaminated food supply. Modern public health experts credit her improvement of sanitation as a key factor in the increased life expectancy of Americans from 47 years in 1900 to 75 years in the mid-1990s.

Richards was born in 1842 to Peter Swallow and Annie Taylor, who had a small farm in Massachusetts. The Swallows, as former teachers, were dissatisfied with the education available to girls and taught their

daughter at home. Richards's formal schooling began when her father located a high school, Westford Academy, that accepted female students. The family moved to Westford, Massachusetts, and purchased a small grocery store. At school, Richards excelled in mathematics and German. At home, she nursed her mother and learned how to run a business by doing the accounting and inventory for the store.

Richards spent two and a half years working as a nurse, tutor, cook, and housekeeper to earn the \$300 needed to attend Vassar College, which she entered at the age of 26 as a third-year student. She excelled at astronomy, studying with Professor Maria Mitchell, who was also a pioneer in American science and a role model for young women who wanted to pursue careers in science. Ultimately Richards decided that chemistry, with its practical applications for improving the environment and human quality of life, would be her life's work.

In 1870, laboratory positions were not open to female chemists. Richards unsuccessfully applied to firms in Boston, Philadelphia, and Dayton. One firm suggested that she apply at the Massachusetts Institute of Technology. Richards's references from Vassar convinced the admissions committee to grant her entrance to MIT as a “special” student. Richards was not charged tuition, and she later learned that she was not included on her class rosters either. The admissions committee had created the “special” status to protect MIT from protests against opening its doors to women.

As an undergraduate student, Richards was in charge of a water sewage study commissioned by the Massachusetts Board of Health. Her results became the standard for Massachusetts's water purity and established Richards as an international expert in water quality analysis. When Richards graduated in 1873, she was not only MIT's first female graduate but also the first woman in the United States to graduate with a degree in chemistry.

Richards met her husband, mineralogist Robert H. Richards, when he asked her to translate an important German mineralogy text. Robert proposed marriage while they were working together in his laboratory. She accepted two years later, once he convinced her that he would not interfere with her scientific career. Married in 1875, they had no children and devoted themselves

to supporting each other's research. While Richards did not have access to graduate students or to a paid position, her husband became the head of MIT's mineralogy department, and his financial support allowed her to continue her work in an unpaid capacity.

Richards's research interests ranged from detecting chemical contaminants in the home, the food supply, and factories to evolution, microscopy, and women's education. In addition to designing curricula and teaching sanitary chemistry at MIT, she traveled to Europe, where she met Ernst Haeckel, who first proposed evolutionary theory to Charles Darwin. Richards so impressed Carl Zeiss that he later would donate microscopes and other instruments to her Women's Laboratory at MIT.

The Women's Laboratory was Richards's effort to allow women to study at MIT. With funds from the Women's Education Association (WEA), Richards opened a facility for women to study chemistry, biology, and finance. She also developed home courses for women through the Society to Encourage Studies at Home. Her efforts to see women admitted to regular degree programs were eventually successful. The Women's Laboratory closed in 1883 after MIT built a coeducational facility. In 1880 Richards founded the New England Kitchen of Boston, which supplied the poor with scientifically nutritious food that they could take home.

When her husband contracted typhoid fever in 1886, Richards conducted the first major analysis of Massachusetts's entire water supply and spent the next 27 years developing and teaching techniques in analyzing water, sewage, and air. She helped found the Seaside Laboratory for the study of ocean and inland waters, which later became the Marine Biological Laboratory at Woods Hole. In the 1890s, Richards began improving sanitation in the home environment, which she called "*oekology*" (Greek for "household study"). In 1893, she supervised the Rumford Kitchen, a model kitchen at the Chicago World's Fair. She also established the American Home Economics Association and the *Journal of Home Economics* to explore consumer aspects of science.

Richards continued her work at MIT until she died from a heart attack on March 30, 1911. In 1878, she was the first female faculty member at MIT and

became a full fellow of the American Association for the Advancement of Science. She was the first woman member of the American Institute of Mining and Mineralogical Engineers (1879) and the first woman to serve as the chief industrial chemist for Boston Mutual Manufacturers Fire Insurance (1883). Richards helped found the Association of Collegiate Alumni, now the American Association of University Women. As the "First Lady of American Science," she opened many doors for women.

Lynda C. Titterington

See also Vol. 1, Sec. 3: Mitchell, Maria

Further Reading

Musil, Robert K. 2014. *Rachel Carson and Her Sisters: Extraordinary Women Who Have Shaped America's Environment*. New Brunswick, NJ: Rutgers University Press.

Richards, E. H. S. 2012. *Euthenics, the Science of Controllable Environment: A Plea for Better Living Conditions as a First Step toward Higher Human Efficiency*. Classic Reprint. London: Forgotten Books.

Swallow, Pamela C. 2014. *The Remarkable Life and Career of Ellen Swallow Richards: Pioneer in Science and Technology*. Hoboken, NJ: Wiley.

Roebbling, Emily (1843–1903)

Though little known or celebrated, Emily Roebbling guided the Brooklyn Bridge project to completion when her husband could no longer do the job. Emily Roebbling took over the job in 1870 and saw the bridge, one of American's greatest architectural and engineering achievements, to completion in 1883.

Born in 1843 to Phoebe and Silvanus Warren, young Emily had a close relationship with her brother Gouverneur Warren. During the Civil War, Gouverneur commanded the Fifth U.S. Army Corps headquartered in Washington D.C. Emily visited her brother in 1864 and met Washington Roebbling. They married in 1865.

Washington Roebbling and his father, John Roebbling, were both civil engineers. John Roebbling was



Emily Roebling became the chief project manager for the Brooklyn Bridge, taking over for her husband in 1870, when he fell ill with decompression sickness. As the bridge's first field engineer, Roebling learned material strength, stress analysis, and cable construction to bring the bridge to completion in 1883. (The Picture Art Collection/Alamy Stock Photo)

also the man principally responsible for the design plans for a new bridge that would connect Manhattan and Brooklyn by spanning the East River. John Roebling, who had designed a number of suspension bridges before the Brooklyn Bridge, was injured when his foot was crushed between a ferry and a piling during a surveying expedition. Unable to continue the project, John Roebling handed the job to his son, Washington. John Roebling died in 1869 from tetanus contracted as a result of his accident. In 1870, Washington Roebling contracted what was at the time called

caisson disease, now known as decompression sickness or, more popularly, "the bends." Massive pine boxes, or caissons, were floated in the river and filled with stones to sink them to the bedrock under the river's bottom. These structures became the bridge's foundations. Many workers, including Washington Roebling, became sick from working on these underwater foundations. Washington Roebling's illness left him paralyzed, bedridden, and unable to continue the project.

At that juncture, his wife, Emily, stepped into the supervisory breach. At first, she served as a conduit between her husband and the crew at the construction site, carrying written messages back and forth between the two. Eventually her role expanded, and she became the project's unofficial chief civil engineer. To do this, she began to study civil engineering on her own. She mastered material strength, cable construction, and stress mechanics. She also managed all the paperwork for the bridge project, answered mail, paid the bills, and much more. Over the 14 years she acted as the chief engineer for the Brooklyn Bridge, she insisted her husband remain the engineer of record. In 1882, city officials determined to remove Washington Roebling as the engineer of record for the bridge project. Emily Roebling fought back, gathering testimony from a number of fellow engineers in support of keeping him on as chief engineer. In doing so, Roebling not only fulfilled current cultural notions of appropriate wifely behavior, but she also saved her own unofficial position as the bridge's actual engineer.

At the Brooklyn Bridge's completion ceremony, Washington Roebling was celebrated, but so too was his wife Emily. Indeed, Emily Roebling was in the first carriage to cross the bridge that day. After the bridge's completion, Emily Roebling moved to New Jersey and designed and built a mansion. She also worked for a number of woman-centered organizations, including Sorosis and the Daughters of the American Revolution. She often wrote and spoke about the inequalities facing women and advocated for increased female equality. She died in 1903. Her husband, Washington Roebling, died in 1926.

While it would be all too easy to dismiss Emily Roebling's contributions to the Brooklyn Bridge as no more than enthusiastic conduit between workers and

her husband, records make it clear that she was the bridge's real construction manager and engineer. Her insistence that her husband remain the engineer of record, while seemingly in line with contemporary notions of modest womanhood, probably contributed to her ability to keep her position as the real chief engineer. A plaque honoring all three Roeblings—John, Washington, and Emily—is affixed to the bridge today as testimony to the family's role in building one of the nation's great bridges.

Peg A. Lamphier

See also Brooklyn Bridge; Steel Arched Bridge

Further Reading

Lewis, Anna M. 2014. *Women of Steel and Stone: 22 Inspirational Architects, Engineers, and Landscape Designers (Women of Action)*. Chicago: Chicago Review Press.

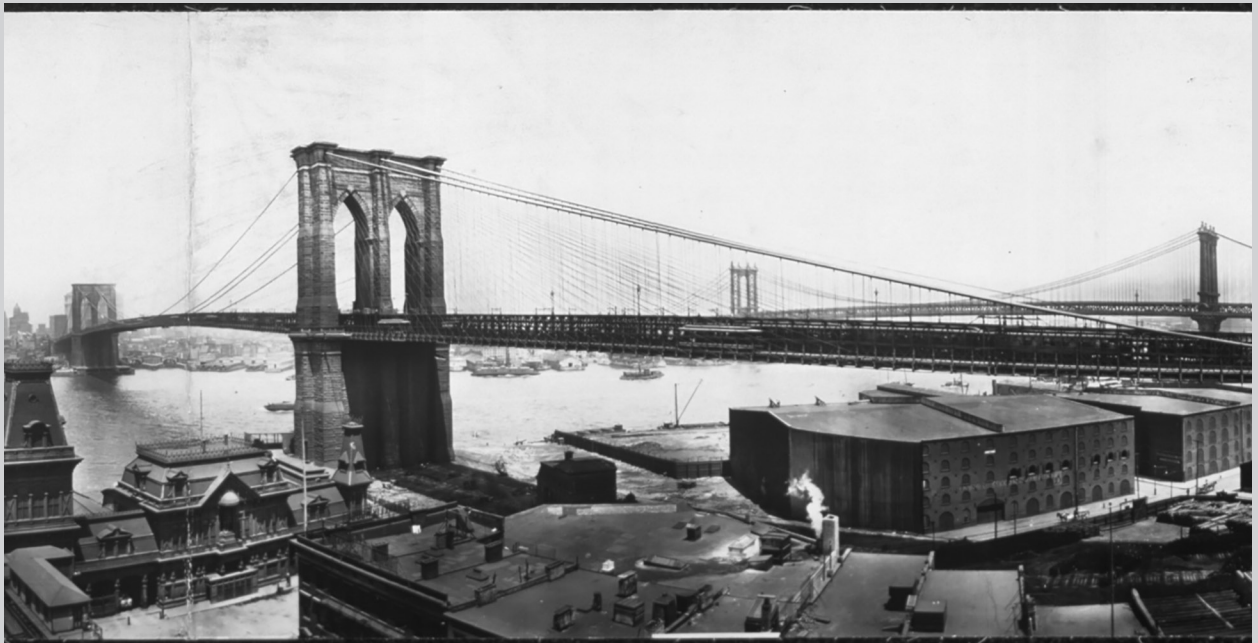
Weigold, Marilyn E. 1983. *Silent Builder: Emily Warren Roebling and the Brooklyn Bridge*. Washington, D.C.: National University.

Primary Document: Photograph of the Promenade on the Brooklyn Bridge (1899)

Emily Warren married Washington Roebling in 1865. Washington took over construction of the Brooklyn Bridge after his father died of tetanus. Soon after, he became so sick that he could not leave his bed. Emily took over for her husband and in the process became the first woman field engineer in the United States. This stereographic card photo shows people walking

along the Promenade of the Brooklyn Bridge in 1899.

Source: On the Promenade, Brooklyn Bridge, New York. Strohmeyer & Wyman, 1899. Stereograph Cards. Prints & Photographs Division; Library of Congress: <https://www.loc.gov/item/today-in-history/june-12/>, accessed August 29, 2018.



Roebling, John (1806–1869)

The civil engineer and designer of the Brooklyn Bridge, John Augustus Roebling, was born on June 12, 1806, in Mühlhausen, Prussia. Along with his

brother, he was an immigrant from Germany that came to United States in the early 1830s. The Roebling brothers founded a farming settlement called Saxonburg in western Pennsylvania. However, Roebling grew tired of farming due to his experience and

interest in engineering; he returned to a series of engineering jobs, including improving a canal system. During this era, boats traveling along canals were loaded onto railcars and were pulled across mountains using steel wire ropes. Because of this, on his Saxonburg farm, Roebling started producing his own wire ropes to use on canal systems. He adopted the method of twisting iron strands into a strong wire rope for durability. He also designed several suspension bridges and aqueducts using this wire rope, which quickly earned acclaims. By the late 1840s, he founded a successful bridge construction and iron wire rope business and moved to Trenton, New Jersey.

Roebling proposed the Brooklyn Bridge as a major civil engineering project during the late 1800s. The Brooklyn Bridge was a contemporary piece of architecture to the steel-arch bridge designed by James B. Eads over the Mississippi river at St. Louis, where it was the world's first major steel suspension bridge. The main parts holding the bridge together such as cables, suspenders, and the truss deck were all made of steel. The Brooklyn Bridge is still actively used and is estimated to carry an average of 145,000 vehicles per day.

When the bridge was constructed, its tower was the second-tallest piece of architecture in the whole of New York, standing at 276.5 feet. The main deck measured 85 feet wide and had a pair of rail tracks in the center for a passenger train between the regular lanes for pedestrians and coaches. It cost three to five cents for pedestrians and vehicles respectively to cross the bridge. Within a year of its completion, it was estimated that 37,000 people a day were using the Brooklyn Bridge to cross the East River and travel between Manhattan and Brooklyn. All the famous steel suspension bridges around the United States today, such as the Golden Gate and Tacoma Narrows Bridge all originated from this design, making Roebling the origin of all steel suspension bridges around the world.

When he started designing the Brooklyn Bridge in 1867, Roebling was already a respected engineer and successful businessperson. He claimed that steel was the “metal of the future” and proposed a plan for the Brooklyn Bridge in which all the suspension cables were made from steel. This was an innovative proposal, and it took the city and the federal government

two years to approve his design. Unfortunately, the same month that the design was approved, Roebling was involved in an accident on a visit to the construction site. His toes were caught and crushed between pier piles and beams by an incoming boat as it bumped against the dock. He then contracted a tetanus infection and seizures, dying 24 days after the incident.

Roebling's legacy lived on as his son, Washington Roebling, took over his late father's role as the chief engineer of the project when construction began in early 1870. Prior to this role, he had assisted his father on other suspension bridge projects and had the knowledge he needed to complete the bridge. Unfortunately, Washington was also faced with his own challenge when he contracted decompression sickness, then known as caisson disease, and he could no longer supervise the construction process. Fortunately for him, his wife, Emily, had assisted in supervising the project with a telescope from their residence. Emily Roebling also learned math and engineering from Washington and served as a communication liaison with the other engineers. Washington went on to serve as the chief engineer for the Brooklyn Bridge project for next 13 years, fulfilling the unfinished work of his father.

There are countless bridges around the world, but the Brooklyn Bridge is a monumental piece of architecture that represents the urban history of New York City. The great landmark has been standing strong since its completion in 1883, and pedestrians continue to visit the raised promenade. In 1964, the bridge was named as a National Historic Landmark. It is one of the major sightseeing spots of New York.

Koyo Takahashi

See also Brooklyn Bridge; Roebling, Emily; Steel Arched Bridge; *Vol. 1, Sec. 2: Canals*

Further Reading

- Ren, Wei-Xin, George E. Blandford, and Issam E. Harik. 2004. “Roebling Suspension Bridge. I: Finite-Element Model and Free Vibration Response.” *Journal of Bridge Engineering* 9, no. 2: 110–18.
- Rose, Andrew T. 2007. “John Roebling's Development and Use of Wire Rope in Western Pennsylvania.”

In *John A. Roebling: A Bicentennial Celebration of His Birth, 1806–2006*, edited by Theodore Green, 1–20. Reston, VA: American Society of Civil Engineers.

Schuyler, Hamilton. 1931. *The Roeblings; a Century of Engineers, Bridge-Builders and Industrialists: The Story of Three Generations of an Illustrious Family, 1831–1931*. Princeton, NJ: University Press.

Roll Film

Roll film, also known as spool or cartridge film, is photographic film wound onto a spool. It replaced earlier glass-plate negatives and revolutionized photography by putting it within reach of the average consumer. Roll film standardized the size of photographs and gave birth to the snapshot.

Earlier photographic processes were cumbersome and dangerous. Glass plates coated with a light-sensitive emulsion served as negatives. They were heavy and fragile. Chemicals were also dangerous: the wet collodion process, introduced in 1851, utilized highly flammable nitrocellulose. Nevertheless, the process was popular because it created very detailed paper prints from glass negatives.

By the late 1870s, photographers were using dry plates coated with a gelatin containing silver bromide. The medium had a greater sensitivity to light, which allowed the photographer to dispense with a tripod. This led to the creation of smaller, lighter cameras that could be handheld.

George Eastman (1854–1932) and Henry A. Strong (1838–1919) capitalized on the new dry process, and in 1881, they formed a partnership and launched the Eastman Dry Plate Company. In 1884, the company name was changed to the Eastman Dry Plate and Film Company, and in 1889, it became the Eastman Kodak Company.

In 1883, Eastman announced roll film. His product consisted of a photographic emulsion coating on paper, which was then loaded in a holder. Eastman made the product available for all existing models of cameras. Eastman was intent on bringing photography within reach of the average consumer, and he focused on mass production to lower costs.

On September 4, 1888, Eastman received a patent for his new Kodak roll-film camera. The wooden camera sold for \$25 and held a roll of film good for 100 images, which needed to be returned to the company for film processing. The camera was heavily advertised with the slogan “You press the button, we do the rest.”

The compact camera was light and easy to use, making it attractive to both men and women. And there was no need to mess with caustic chemicals because the roll film could be conveniently processed. Eastman followed this success with the introduction of the inexpensive Brownie camera in 1900. It retailed for \$1 and used roll film that sold for only 15 cents.

In 1908, Kodak introduced a film that used cellulose acetate as a base layer, which was a safer alternative to the earlier, flammable film. The company introduced Kodachrome color transparency (slide) film in 1935 and Kodacolor negative film in 1942.

Roll film lost much of its market share in the latter part of the 20th century as digital cameras became widespread, but it is still in use by professionals and amateurs. In recent years, there has been a renewed interest in film photography.

Karen S. Garvin

See also Camera; Celluloid; Eastman, George; Photographic Film; *Vol. 3, Sec. 1*: Land, Edwin H.; Polaroids; *Vol. 3, Sec. 2*: Digital Photography

Further Reading

Brayer, Elizabeth. 1996. *George Eastman: A Biography*. Baltimore: Johns Hopkins University Press.

Gustavson, Todd. 2009. *Camera: A History of Photography from Daguerre to Digital*. New York: Sterling.

Marquardt, Chris, and Monika Andrae. 2016. *The Film Photography Handbook: Rediscovering Photography in 35mm, Medium, and Large Format*. Santa Barbara, CA: Rocky Nook.

Roller Coaster

Commonly found in amusement parks, roller coasters are generally elevated railroads featuring extreme ups and downs, including loops, tight turns, and even

inversions. Roller coaster cars are traditionally open, with riders strapped inside. Most roller coasters are of the “train type,” with multiple cars hooked together, though a minority use single cars. Roller coasters can be operated as complete circuits or as shuttle coasters, which begin in one location and end in another. Roller coasters are differentiated from scenic railway rides in that the latter ride sedately upon the ground, creating entertainment from the scenes the railway passes rather than the motion of the train cars.

LaMarcus A. Thomson (1848–1919) invented the first roller coaster. Known as the “Father of the Roller Coaster,” Thompson developed a number of “gravity rides,” or amusement park rides that used gravity power, rather than steam power as did traditional railroads of the time. Thompson’s first great roller coaster, the Gravity Pleasure Switchback Railway, debuted on Coney Island in 1884. In 1884, Thompson introduced the first scenic amusement railway ride at Coney Island in New York. The Thompson railway took riders past European landscape scenes and proved an immense success with amusement park goers looking for gentle entertainment. Hundreds of scenic railways opened in amusement parks across the country, the most famous of which is the Disneyland railway in Anaheim, California.

Ewin Prescott patented an improved roller coaster in 1899 that was the first to incorporate a loop into its design. Prescott’s patent letter describes a coaster with parallel tracks with steep gradients and circularly arranged loops. Cars were held to the track by centrifugal force (as were the people in the cars).

By the 1920s, amusement parks across the United States and the world featured roller coasters, from Coney Island’s iconic Cyclone, which opened in 1927, to the Giant Dipper on Santa Cruz, California’s boardwalk. Still in operation today, the Giant Dipper has seen over 60 million riders.

The so-called Golden Age of roller coasters and amusement parks ended with the advent of the Great Depression in 1929. The 1970s and 1980s saw a renaissance in amusement parks, pushed in part by a resurgence of interest in roller coasters. Modern roller coasters are made of steel rather than wood, allowing for greater sturdiness and reduced maintenance costs.

Despite the seeming dangers of roller coaster riding, the U.S. Consumer Product Safety Commission reports that they are relatively safe, particularly compared to some other recreational activities. A 2001 report established that two people were killed out of 319 million Six Flags amusement park roller coaster riders, showing that roller coasters are considerably safer than most sports as well as riding in an automobile.

Peg A. Lamphier

See also *Vol. 1, Sec. 3:* Electric Street Railway; Railroads; Roller Skates; *Vol. 3, Sec. 3:* Video Game

Further Reading

Weisneberger, Nick. 2015. *50 Groundbreaking Roller Coasters: The Most Important Scream Machines Ever Built*. CreateSpace.

Wolcott, Victoria W. 2012. *Race, Riots and Roller Coasters: The Struggle Over Segregated Recreation in America*. Philadelphia: University of Pennsylvania Press.

Rotary Washing Machine

While other models of mechanical washing machines were appearing in other countries as well as the United States, Nathaniel Briggs invented the first mechanical washing machine in 1797—but that design was really no more than a washboard. James King patented the first drum machine in 1851, and though it resembled modern machines, it was hand powered. In 1858, Hamilton Smith invented a rudimentary rotary washing machine.

But it was Margaret Colvin of Michigan who introduced the first largely successful product, the Triumph Rotary Washer, in 1876, which took off after being exhibited at the 1876 World’s Fair in Philadelphia. Colvin’s husband initially marketed and made the machines, which were the most effective at the time because the “rotary” part of the machine involved rollers through which clothing would be fed in order to squeeze and extract the dirt.

While commercial laundries used steam-powered engines, home-use washing machines were either hand powered or run by single-cylinder, gasoline-powered engines until homes became electrified. Though the first electrically powered washing machine

was invented in 1880, they were not readily available until the 1930s.

Before the introduction of machines, the washer (generally a woman) had to scrub clothes on a washboard at a local river or hand-carry water to be heated on a fire in the home. Early machines simply provided hand-cranked rollers that moved clothing into a sink to be rinsed in clear water. Once rinsed, the clothes were fed manually back into the rotary rollers to remove excess water. The process to wash a “load of laundry” took an entire day, and this did not include drying and ironing the clothes.

From 1862 and 1894, 48 American women patented washing machines along with other items that contributed to the modern washing machine, such as wringers, drainers, and strainers. Around 2,000 patents had been given in the United States alone. By 1920, over 700 American companies were producing washing machines, such as Maytag, Bendix, and Whirlpool. These mostly appeared in upper-class homes or laundries for those of lesser income. It was not until the post–World War II period, when the GI Bill allowed for so many veterans to purchase homes in the newly created suburbs, that washing machines became a regular appliance in most homes. Even apartment buildings set aside areas for a laundry room to entice renters.

In the 21st century, washing machines require much less labor because they are nearly completely automatic. Oddly, household statistics suggest that women spend as much time doing laundry in the 21st century as they did a hundred years earlier. The reason lies in clothing cleanliness standards. The easier machines became to use, the more clothes Americans bought and the cleaner they had to be, thus belying the myth of the “modern convenience.”

Rosanne Welch

See also Folding Cabinet Bed; Harvard Computers; Vol. 1, Sec. 2: Internal Combustion Engine; Steam Engine; Vol. 1, Sec. 3: Sewing Machine, Automated

Further Reading

Boothroyd, Jennifer. 2011. *From Washboards to Washing Machines: How Homes Have Changed*. New York: Lightning Bolt Books.

Rowing Machine

Rowing machines simulate watercraft rowing. They are used both for training athletes in rowing events and for general physical fitness. William B. Curtis patented the first rowing machine in 1871.

Though simple rowing machines have existed for centuries, William B. Curtis patented an improved rowing machine that allowed the rower to practice through Chicago’s cold winters, when Lake Michigan’s surface froze. Curtis’s machine used a hydraulic damper design that improved rowing resistance. The design did not adequately mimic actual rowing, nor did it measure a user’s power generation in any manner. By 1900, rowing machines using pneumatic resistance had gained in popularity over the Curtis design, though they had the same weaknesses.

In the 1950s, Australian John Harrison built a friction brake machine that featured a large flywheel that allowed the rower to account for the weight and drag of a real boat. This rowing machine was the first to accurately measure the user’s power output and the rower’s range. In the 1970s, Norwegians made further improvements to the rowing machine.

Today, the rowing machine is used in home and public gyms. There are rowing machine competitions, culminating in the World Indoor Rowing Championships held in Boston each February. Computer and Internet technology have contributed to the popularity of rowing machine competitions, many of which are now online.

Peg A. Lamphier

See also Vol. 1, Sec. 1: Schooner; Vol. 3, Sec. 1: “Air” Athletic Shoes; Vol. 3, Sec. 2: Internet

Further Reading

Albert, Albert. 2017. *Rowing Machine Workout: Rowing for Beginners*. Independent.

Saccharine

Saccharine, an artificial or nonnutritive sweetener, was discovered in 1879 by Johns Hopkins University chemist Constantin Fahlberg.

Fahlberg had hoped to discover a new food preservative using derivatives of coal tar. Widespread industrialization made this by-product of carbonized or gasified coal abundant, and similar organic compounds were already used for preservation and flavoring. After producing one apparently unremarkable batch, Fahlberg lifted a cigarette to his mouth and serendipitously tasted residue from the solution. He noted its extreme sweetness and took to calling it “saccharine,” meaning of or similar to sugar.

Fahlberg quickly grasped the commercial potential of his product. He continually refined and tirelessly promoted saccharine, attracting several large New York beverage makers by 1885. Fahlberg soon took saccharine international through a German industrial business syndicate, and together, they held a 15-year virtual monopoly over saccharine production and new coal tar derivation. This monopoly lasted until 1901, when John Francis Queeney, an independent sales agent with the German syndicate, established the first saccharine manufacturing plant in the United States. Queeney branded his company Monsanto Chemicals.

Fahlberg, the syndicate, and independent businessmen like Queeney marketed saccharine to food and beverage manufacturers over individual consumers. This wholesale strategy ensured exponential growth for Fahlberg and his partners, while manufacturers recognized the solubility of saccharine, its relative cheapness vis-à-vis sugar, and the volatility of sugar-producing states.

Significantly, even as saccharine was used in an increasing number of products, a few consumers registered the presence of the nonnutritive sweetener. This and similar issues proved divisive in an era of controversial additives; opium- and cocaine-ridden patent medicine, along with mislabeled foodstuffs, were cited as reason for passing the 1906 Pure Food and Drug Act. A classic piece of progressive-era legislation, the law essentially required truthful labeling by outlining criminal penalties for misbranding and adulteration. After the act, products made with saccharine had to be labeled as such.

Harvey Wiley, chief chemist of the U.S. Department of Agriculture, and his team of scientists had

been studying several food preservatives and their effects since 1902. Wiley compiled a list of adulterants, including saccharine, to be banned based on these trials. Yet, as historian Carolyn de la Peña has noted, adverse health effects were difficult to conclusively demonstrate in these potentially dubious studies. In any case, Wiley faced opposition from President Theodore Roosevelt, who enjoyed saccharine at the advice of his doctor. Physicians frequently recommended saccharine to alleviate ailments such as diabetes or, in Roosevelt’s case, obesity. The president appointed another panel to study the sweetener, which found that saccharine was not harmful in small amounts, but also that it contained no nutritional value.

This highly publicized ruling on saccharine gave beverage advertisers plentiful fodder. Companies attacked competing saccharine-laden products as unnatural, nauseating, and a swindle to boot. Sugar provided more calories per serving and was understood as an integral part of a balanced diet. Consumers largely rejected saccharine, even throughout the sugar rationing of World War I. By the late 1920s, saccharine purchases were generally limited to diabetics and the conscientious obese.

Saccharine became a household product during and after World War II. Rationing directed the majority of sugar output to men fighting overseas, as double dessert servings and seemingly limitless Coca-Cola in mess halls attested. Government propaganda asked women to forgo sugar carbohydrates for their husbands and sons’ nutrition. Many women answered this sacrifice with the use of saccharine. At that time, saccharine was typically available in pharmacy sections of stores. It came in tablet form, packaged in a pill bottle. Women often discreetly withdrew saccharine tablets from packaging when in public until manufacturers noticed surging demand and began marketing decorative containers and inconspicuous packets.

The expanding postwar economy had a similar effect on the postwar diet. At the same time, a growing body of nutrition science linked excess calories with poor health. Sugar had lost much appeal in kitchens following the Great Depression, wartime rationing, and the general stigma of excessive consumption.

By the late 1950s, full lines of products supplied saccharine where sugar was shunned. These included sodas, jellies, and even salad dressings. Consumers could also add granulated saccharine to items of their choosing with Sweet'n Low packets, which debuted in 1957.

The U.S. Food and Drug Administration (FDA) took interest in saccharine as it exploded in popularity. Studies throughout the 1950s and late 1960s were inconclusive, but in 1971, scientists revealed through animal experimentation a potential risk for bladder cancer. A 1977 trial by the Canadian Health Protection Branch confirmed these findings (though only in extreme circumstances), and in March of that year, the FDA announced its intention to ban saccharine on January 1, 1978.

This statement incited a consumer revolt. Hundreds of thousands of letters swiftly flooded the FDA and elected representatives. Writers mocked the results, which indicated that humans would have to drink the equivalent of over 800 diet sodas per day. Some advocated for individual choice, but most frequently shared stories of weight loss enabled by saccharine. This outpouring was organic, but the \$2 billion artificial sweetener lobby soon mobilized in defense of its product with full-page ads in nationwide papers. The FDA soon yielded to mounting political pressure and retreated from its stance on banning saccharine.

Saccharine sales remained ascendant until the early-to-mid-1980s, when aspartame, branded as NutraSweet, was introduced to grocery shelves nationwide. Profits dwindled, but Sweet'n Low and generic saccharine brands are still available in supermarkets. Americans continue to consume ever-proliferating brands of artificial sweeteners, including Equal, Splenda, and Truvia. Twenty-first-century nutrition researchers note that generations of artificial sweetener usage has not resulted in slimmer Americans. Some studies suggest that the human body metabolizes all sweeteners the same way, regardless of their caloric content, while bioethicists suggest that artificial sweeteners have not been sufficiently tested to determine their safety. Thus, the controversies about artificial sweeteners continue.

Kyle Bridge

See also *Vol. 3, Sec. 1: Aspartame*

Further Reading

de la Peña, Carolyn. 2010. *Empty Pleasures: The Story of Artificial Sweeteners from Saccharine to Splenda*. Chapel Hill: University of North Carolina Press.

Silo

Fred Hatch is the American agricultural inventor of the towering, vertical silo that is often found in the Midwest beside a barn. Farm grain wasn't always stored in silos; it was stored in pits that farmers had to dig out, which caused excess spoilage in many instances.

Influenced by the grain storage pits and corn cellars of Native Americans, the first-known wooden tower silo was constructed in 1873 by Fred Hatch, who lived in McHenry County, Illinois. Hatch had just graduated from Illinois Industrial University, now known as the University of Illinois. At that time, there were few textbooks on agriculture. The only faculty member in the agriculture department at the university was Professor Willard Flagg Bliss, who improvised by translating foreign papers and other literature on similar topics. Hatch worked with Bliss in an effort to understand silo mechanics.

After college, in 1873, Hatch went back to his father's dairy farm in Spring Grove, Illinois. As a member of the Illinois second graduating class, he was eager to reveal what he'd learned at college. In the fall of that year, Hatch convinced his father, Lewis, to build a structure inside the barn to hold silage. He and his father dug a 10-foot x 16-foot rectangular hole that was 8 feet deep. They surfaced it with rocks, mimicking the way that basement walls were built in that period. The Hatches extended the walls above the surface another 16 feet, with multilayered flooring of two different thicknesses. The new design helped relieve rain spoilage and made the silo faster to fill, empty, and pack. It set the stage for another innovation with a separate roof on the silo. The silo would eventually be built outside of the barn.

That next fall, the men loaded the newly innovated silo with corn silage. Almost instantly, the cows stayed

heavier and delivered more milk than ever before. Until the 1870s, year-round dairy farming had hardly ever been an option due to harsh winters or because of the difficulty in providing sufficient moist feed for dairy cows to maintain milk production. But storing the silage in an airtight container stopped the fermentation process, preserving the feed until desirable, and most important, it helped create a boom in the dairy market.

Not remaining complacent, in 1876, the Hatches constructed two more silos, again indoors. Just like the original silo, they were identical in size; the only difference was that the subfloors were made of concrete instead of stone. Fred and his father knew they had an incredible innovation but never took advantage of the potential market. In that period, nearly 80 percent of Americans labored on farms and were in the need of this type of innovation, but farmers were slow to invest in this concept of crop preservation.

Years later, the use of silos spread by word of mouth and through several farming magazines. By 1924, there were more than 100,000 documented in the United States alone. During World War I, this was extremely important since farmers were being asked to generate more food to contribute to the war effort. Patriotic silo buildings alongside large barns were seen as a farmer's wealth.

The first upright silos were rectangular and often built of stone, sometimes limestone. They were expensive and often took months to build. They were not very tall. Even though their interior walls were two to three feet thick, they still could not resist the pressure of the kept silage. Though coated inside with cement, the silos cracked, allowing air to enter that would eventually ruin the silage. Cracks also allowed water to penetrate, and when it froze, it created more cracks. The corners of square silos also created many issues. In the 1890s, farmers began using round silos to solve this problem.

Through the years, silos have continued to evolve and have been built of wood, fieldstone, tile, brick, concrete, and steel. They have ranged in height from 35 to 60 feet. Beginning in the 1930s, barns and silos along state roads were sometimes used to advertise products or even annual events, grabbing attention and creating noise in the community like billboards in

today's era. With continued innovation, silos unfortunately also created a variety of other concerns besides the rotting of silage. Silage, as it ferments, produces many toxic gases, including nitrogen dioxide and carbon dioxide, which can be deadly if a silo is entered too soon after filling. There is also a newly found condition called "farmers lung," which is caused by molds in the top layers of silage. And when it freezes, silage sticks to the walls of a silo; there are many reports of farmers being injured by falling silage.

If it were not for Fred Hatch's work, farming might have been a completely different process today. His family's three silos were in continuous use until the late 1920s, when the farm changed ownership and the barn and silos were destroyed. However, in Spring Grove Park, a permanent marker remains memorializing Fred Hatch, the builder of America's first upright silo.

Dylan Keys

See also *Vol. 1, Sec. 1: Food Production, Native American*

Further Reading

Buxton, Dwayne R. 2003. *Silage Science and Technology*. Madison, WI: American Society of Agronomy.

Down, A., et al. 2016. "A Classic Piece of Pomfret Scenery Comes Down." *The Vermont Standard*, October 10. <https://www.thevermontstandard.com/2016/10/a-classic-piece-of-pomfret-scenery-comes-down>, accessed August 29, 2018.

Graham, Judith. 2011. "Drowned in Corn: Grain Bin Deaths Hit Record." *Chicago Tribune*, March 8.

Skyscraper

Even today, the skyscraper is the icon of American business and a symbol of economic might. The skyscraper also represented a cultural revolution in office and real estate management. It offered a solution to the high cost of prime city real estate. For years, building height was limited by the strength of materials, insufficient water pressure, and the ability of people to climb steps to their offices. In the 1880s, buildings

over six stories were rare. Buildings carried their weight through the frames versus the internal skeletal structure. The Home Insurance Building in Chicago is recognized as the first skyscraper.

The Home Insurance Building was 10 stories high (138 feet). It was the first building to be supported on the outside and inside. It was also the first building to fully use steel frame technology. Skeletal support, not height, was the defining characteristic of the skyscraper. It was technically possible to build up to 10 stories with stone framing. The Flaxmill Building in Shrewsbury, England, was a cast-iron-framed building in 1797 that rose 11 stories. Six-story buildings became common with wrought iron beams and the invention of Elisha Otis's safety elevator in 1854. The Otis elevator had premiered at the Great Exhibition of 1851.

Cast-iron frames had become popular, but steel was needed for internal structures strong enough to carry the building's weight. Cast iron was popular because of its fireproof nature, since fire was a major threat to city buildings of the time. Stone and cast-iron beams had been used in the early 1800s, but true internal weight-bearing construction required the strength of steel. Wrought iron beams were an intermediate solution that Peter Cooper had pioneered in New York. Steel, however, offered the strongest material available. Steel has three to four times the tensile strength of cast iron. Steel was in very limited supply until the development of the Bessemer steel process in the 1860s; prior to 1870, Bessemer steel was not available in large enough quantities for building. Steel also had to prove itself, and that took place in bridge building. The demonstration of the load-carrying strength of steel would be the Eads Bridge in St. Louis in 1874. The 520-foot bridge was the brainchild of America's steel man Andrew Carnegie. Bridge designer James Eads had to convince Carnegie that steel could be used. Carnegie, however, had no steel mills at the time and had to purchase steel for his Keystone Bridge Company. The success of the Eads Bridge would usher in the age of structural steel for construction.

Carnegie would become a believer in steel, opening up his great Bessemer steel plant at Braddock, Pennsylvania, in 1875 and following it with his



The 1885 Home Insurance Building in Chicago was the world's first skyscraper. William Le Baron's steel frame design allowed for revolutionary building height and stability, opening an era where city builders built increasingly tall structures. (Chicago History Museum/Getty Images)

massive, open-hearth structural mill at Homestead, Pennsylvania, in 1890. Carnegie would supply the structural beams for the building of the Brooklyn Bridge in the early 1880s. In 1883, it would be Carnegie who would sell steel to the Home Insurance Building architect, William Le Baron Jenney. Jenney had originally planned to use wrought iron beams and had actually started with wrought iron framing. Jenney actually built six stories before Carnegie convinced him to switch to steel beams. Jenney's use of steel framing won him the title of the "father of Chicago steel construction." The use of steel dropped the cost of insurance dramatically. The second steel frame building would come in 1886 with the building of Chicago's 12-story Rookery. Carnegie would build a 15-story skyscraper in Pittsburgh in 1890 using the "Chicago skeleton."

The use of steel in skyscrapers was followed by its use in constructing fireproof factories. H. J. Heinz started his fireproof three-story factory in 1889. Most of America's cities had been devastated by fires, and insurance costs had soared by the 1880s. Fire was one of the main reasons that many companies failed. Fires had destroyed many American cities such as Chicago, Boston, and Pittsburgh. H. J. Heinz Company built its factory to be completely fireproof with steel beams and concrete fill between floors, which brought significant insurance savings for the company. The infrastructure was of structural steel from Carnegie Steel. The popularity of skyscrapers created a revolution in steelmaking and construction. Bessemer steel's limits were being reached in the late 1890s at around 12 stories of height. Structural beams required the higher-quality open-hearth steel to move beyond 12 stories. Carnegie purchased a brand-new Bessemer steel mill at Homestead and gutted it to make open-hearth steel for the structural steel market that would move buildings skyward.

Skyscrapers were as much a cultural as a technological advance. In the late 1890s, skyscrapers started to be viewed as real estate and rentable office space. Culturally, the New York World Building in 1899 is considered the first modern skyscraper. The New York World Building was built as commercial real estate versus a corporate headquarters. The New York World Building was financed by banker August Belmont as a real estate investment. The building had 950 separate offices to rent, and 4,000 people worked there. The New York World Building was 30 stories and 391 feet high. Chicago and New York became true business centers with these huge office buildings. The World Building also featured the electric elevator of Werner von Siemens, which was also a necessary technology for 30-plus-story buildings.

The next critical step in taller skyscrapers (moving beyond 30 stories) was the production of the Bethlehem Steel I beam. The I beam was lighter, but its design gave it more strength than the structural beams used at the time. The I beam was the invention of engineer Henry Grey, but it took the financing and building of a special rolling mill to make it a reality. Charles Schwab of Bethlehem Steel in 1907 made the investments necessary to change American skylines. Schwab

used his business connections to overcome the resistance of engineers and architects to using the new technology. The I beam was lighter and stronger, but it cost triple what the older H beam did. I beams gained popularity with their use in buildings for Gimbel Brothers, the Field Museum, and the Chicago Opera House. The beam quickly gained export markets. In 1909, the United States produced less than a million tons of I beams, but in 1929, it produced over 4 million tons of them.

There were many doubters, but the beam's use in New York's Metropolitan Life Building of 50 stories (700 feet) proved it to be a success. The Bethlehem I beam went on to change the skylines of Chicago and New York, with the Chrysler Building in New York reaching 77 stories (927 feet) in 1930 and the Empire State Building reaching 102 stories (1,250 feet) in 1931. Skyscrapers are great symbols of economic might. Today, we have the 2,717-foot, 160-story Burj Khalifa in Dubai.

Quentin R. Skrabec

See also Carnegie Steel Mill; *Vol. 2, Sec. 2*: Empire State Building

Further Reading

- Condit, Carl. 1964. *The Chicago School of Architecture*. Chicago: University of Chicago.
- Moudry, Roberta. 2005. *The American Skyscraper: Cultural Histories*. Cambridge: Cambridge University Press.
- Oxlade, Chris. 2006. *Skyscrapers: Uncovering Technology*. Tonawanda, NY: Firefly Books.
- Sabbagh, Karl. 1991. *Skyscrapers: The Making of a Building*. New York: Penguin Books.
- Turak, Theodore. 1986. *William Le Baron Jenney: A Pioneer in Modern Architecture*. Ann Arbor: University of Michigan Press.

Soda Fountain

A soda fountain is a mechanical device that dispenses carbonated beverages, or sodas. In the 19th and early 20th centuries, a soda fountain was a small lunch counter, usually inside a larger store—often a drug store.

The soda fountain was invented in the United States because people drank carbonated water in the belief that it had medicinal qualities. This viewpoint had come from as early as 400 BC. Hippocrates, an ancient Greek philosopher often regarded as the father of modern medicine, insisted that carbonated water cured diseases. From the 1300s to the 1600s, aspiring and amateur scientists experimented with creating artificial mineral or carbonated water. It was not until the 1770s that Joseph Priestley, an English preacher, found a way to create it by forcing fermentation gas from a brewery into plain water.

In the early 1800s, Benjamin Silliman, a teacher in Connecticut, made a breakthrough in developing the soda fountain. Suffering from depression in 1797, he visited the well-known Saratoga and Ballston Spas in New York State. He then took a job teaching chemistry and met Joseph Priestley. Silliman then traveled to London, where he witnessed the flourishing bottled mineral water industry, which influenced his desire to work in the field when he returned to the States in 1806.

Silliman used a “Nooth’s apparatus” to manufacture the carbonated water and found an apothecary in New Haven, Connecticut, to sell it. While demand was high for his water, he had no reliable bottles to put it in because Americans had not yet perfected glass bottles that could withstand the pressure of the carbonization. Instead, Silliman decided to use imported mineral water bottles from England. By selling mineral water in this fashion, he created the idea that the beverage could be enjoyed along with other people from all segments of society. They could gather and socialize while sipping their beverages at soda fountains.

During Silliman’s time, apothecaries used large contraptions to distribute carbonated water to their customers. Columns, urns, and faucets shaped like goose necks were the norm in dispensing the beverage. One of Silliman’s competitors, Joseph Hawkins, was another pioneer in selling mineral carbonated water to the masses. He also sold the beverage by the glass, and he manufactured carbonated water with a machine he invented in 1807.

As the years passed, soda fountains became elaborately decorated, using carved wood, polished marble, and beveled mirrors. Commonly, spigots were

shaped like goose necks and adorned with eyes, beaks, and bills. Urn-type fountains could include more than one spigot and could hold ice to keep the carbonated water cold. Urn spigots were decorated to look like fish, elephant’s trunks, or another animal. Urn-based fountains were made from bronze or silver-plated metal. Moldings and figurines were added for decoration.

“Soda jerks,” the men (generally) who worked at soda fountains, developed a number of novelty drinks by combining flavored syrup with carbonated water. Coca-Cola, for example, was originally sold as a syrup. Eventually, soda fountains added ice cream-based treats to their menus and sometimes light lunch fare like sandwiches and soup.

The soda fountain’s popularity and advancement continued into the mid-20th century. Post–World War II culture and the drive-through restaurant gradually caused the soda fountain’s popularity to decline, though a few of them still exist.

Marilyn Chin

See also Coca-Cola; Ice Cream Soda; *Vol. 2, Sec. 2: Blender*; *Vol. 3, Sec. 1: TV Dinner*

Further Reading

Donovan, Tristan. 2014. *Fizz: How Soda Shook Up the World*. Chicago: Chicago Review Press.

Funderberg, Anne Cooper. 2001. *Sundae Best: A History of the Soda Fountains*. Bowling Green, OH: Bowling Green State University Popular Press.

Spork

A spork is a hybrid eating utensil that combines the properties of a spoon and a fork into one piece of flatware. Sporks have a bowl shape similar to a regular spoon as well as several tines for spearing food.

The spork is not a new invention. In February 1874, Rhode Island doctor Samuel W. Francis received a patent for his “improvement in combined knives, forks, and spoons.” His awkward-looking utensil looked like a spoon with four tines on the business end and a short, flat blade that was grafted to one side of the bowl. Other fork-and-spoon combinations have

been in vogue at various times, although most have consisted of a flat handle with a spoon at one end and a two-tined fork at the other end. These utensils were used as serving tools rather than for eating.

The word “spork” dates back to at least 1909, when it first appeared in a dictionary. Since then, several patents and trademarks have been issued for a variety of spork designs. Modern sporks come in a variety of designs and are manufactured from plastic, stainless steel, aluminum, and titanium.

Karen S. Garvin

See also *Vol. 2, Sec. 2: Blender; Vol. 3, Sec. 1: TV Dinner*

Further Reading

Wayland-Smith, Ellen. 2012. *Oneida: From Free Love Utopia to the Well-set Table*. New York: Picador.
 Wilson, Bee. 2012. *Consider the Fork: A History of How We Cook and Eat*. New York: Basic Books.

Steel Arched Bridge

In the city of St. Louis, right above the longest river of the United States, a bridge designed by James B. Eads has stood as one of most iconic structures since its 1874 opening. As an historic piece of architecture with elegant structure and unconventional design at the time, it has claimed numerous records as a bridge. At the time of completion, the Eads bridge was considered the longest steel arched bridge in the world, was the first bridge over a river in St. Louis, and was the southernmost bridge of the Mississippi river.

Eads made innovative use of steel and iron as main structural components to create a bridge that defied then-conventional wisdom. However, the path from design to construction of this immediate post-Civil War architecture was not as straightforward as it appears. The creator was as amazing as the creation itself. Eads was known as genius who taught himself to create the bridge without any prior experience. The entire project involved a series of struggles as well as political, legal, and medical issues. But the some of the other famous bridges around the United States

today all originated from his design. Eads acted as a bridge to innovation for the modern builders of today’s steel bridges.

The creator of the eponymous Eads bridge, James Buchanan Eads, was born in Lawrenceburg, Indiana, in 1820. He had limited access in academics due his parents’ financial problems. In 1883, as a penniless 13 year old, Eads arrived in St. Louis, Missouri. He first sold apples on the street, but then he moved up to a position as a clerk with a merchant named Barrett Williams. Williams possessed a private library and allowed Eads to read from his collections. This sparked an interest in Eads specifically in the problems of steamboats and their frailties. During this era, boats were liable to many mechanical dangers and often sank with expensive freights aboard. Business owners usually paid fortunes to recover these sunken cargos. Noticing a business opportunity, Eads created a submersible boat and a salvage business. He made a fortune from this first business and was able to retire by the age of 37 in 1857.

When the American Civil War started, Eads volunteered to assist the Union Army in creating an innovative battleship. In 1861, Eads entered a contract to build seven of these ships, which were called “ironclads.” They were covered by iron plates and carried large cannons. His ironclads debuted earlier than the famous ironclad CSS *Virginia* by John Ericsson.

With the conclusion of the Civil War, Eads came across the opportunity to create a steel bridge. Long-standing plans to create a bridge across the Mississippi in St. Louis had been revived because the river prevented the transportation of cargo in bulk by train. Without the bridge, freight had to be dropped off the train and loaded onto a ferry to cross the river, only to require a reverse of the process on the other side. This significantly raised the cost of transportation and discouraged businesses from shipping goods through St. Louis. Not only that, but some Chicago businessmen purchased the rights to a St. Louis bridge so that no one else could do it.

Despite this sabotage by the Chicago businessmen, the city of St. Louis proceeded to create the new bridge. But Eads faced another complication: his plan was considered too radical. It did go forward, but the

project caused 15 deaths and two permanent disabilities, and 77 others were severely injured. As the bridge neared completion on July 2, 1874, the builders ensured that the bridge could withstand 5,000 pounds per linear foot. On July 4, 1874, Eads's steel arched bridge officially opened, making it the world's first and biggest steel-arch bridge.

Between 1875 and 1879, Eads partook in building the first permanent mouth of the Mississippi River into the Gulf of Mexico by guiding sediment deposits. In 1884, Queen Victoria of England presented Eads with the Albert Medal of the Royal Society of Arts. This medal is awarded to an individual who proves distinguished merit in promoting arts, manufacture, and commerce. He was the first non-British person to receive the award. During the final years of his life, he worked on a project to cross the Isthmus of Panama. However, he opposed the Panama Canal project planned by Ferdinand de Lesseps and proposed the idea of a ship railroad instead.

On March 8, 1887, Eads suddenly passed away while recuperating in Nassau, Bahamas, bringing an end to his 66 years of life. Eads was a true inventor and an engineer who made a significant impact on the daily lives of citizens in his time and to this day. In fact, when the deans of U.S. engineering colleges were asked to vote on history's five greatest engineers, they selected Leonardo da Vinci, James Watt, Ferdinand de Lesseps, Thomas Edison, and James Buchanan Eads.

Koyo Takahashi

See also Edison, Thomas; *Vol. 1, Sec. 2: Steamboat; Vol. 2, Sec. 2: Panama Canal*

Further Reading

Kouwenhoven, John A. 1981. "James Buchanan Eads: The Engineer as Entrepreneur." In *Technology in America: A History of Individuals and Ideas*, edited by Carroll W. Pursell, 80–91. Cambridge, MA: MIT Press.

Weingardt, Richard G. 2005. "James Buchanan Eads." *Leadership and Management in Engineering* 5, no. 3: 70–74.

Yager, Rosemary. 1968. *James Buchanan Eads: Master of the Great River*. New York: Van Nostrand.

Stethoscope, Binaural

The stethoscope, commonly seen worn around the necks of medical personnel, is an important tool used to listen to sounds created by internal organs of the body. The modern binaural, or two-ear, stethoscope comprises a flat, disc-shaped resonator and two flexible tubes connected to a pair of ear pieces. The membrane of the resonator is placed on the patient's body to auscultate, or listen, to the sounds produced by the heart, lungs, blood vessels, and gastrointestinal tract. The word "stethoscope" is derived from the Greek "*stethos*" for "chest" and "*skopein*" for "examination."

Before the stethoscope was invented, early physicians used percussion or immediate auscultation to listen to a patient's chest. Similar to using a drum, percussion involved tapping on the chest and listening for sounds that indicated if the patient's lungs were congested with fluid. Auscultation provided more accurate results. Physicians placed their ears directly upon the patient's chest to hear heart and lung sounds more clearly.

Direct auscultation had several disadvantages. First, the skin-to-skin contact between physicians and patients increased the chances that a doctor might contract a louse infestation or other infection from the patient. At the very least, such close contact tended to be unpleasant if the patient had not bathed. Second were the technical concerns. The technique required careful placement of the ear and a quiet environment. Physicians often missed hearing important sounds that might indicate illness because the sounds weren't amplified and could be further muffled by excess tissue in muscular or obese patients. Finally, there were modesty issues associated with examining female patients.

The first stethoscopes widely in use were wooden tubes and were monoaural (they used one ear). In 1816, French physician Rene Laennec was uncomfortable performing direct auscultation on a plump, young female patient. He remembered seeing two children playing with a piece of wood and a pin; one child would scratch the wood with the pin, and the other would listen to the signal produced on the other end. Laennec rolled a sheet of paper into a tube similar to a hearing aid known as an ear trumpet and discovered that he

could hear the patient's heart sounds very clearly. Laennec used his stethoscope to investigate heart and lung sounds and compared his noninvasive diagnoses to observations made during postmortem examinations. The stethoscope allowed him to identify the different lung sounds produced by pneumonia, bronchiectasis, pleurisy, emphysema, and pneumothorax.

The first binaural stethoscope was proposed in 1829, when Nicholas Comins devised a hinged stethoscope that allowed the physician to assume more comfortable positions during examinations. Comins's sketches showed a binaural instrument, but it was not further developed. Around 1840, Dr. C. J. B. Williams constructed a binaural stethoscope using two bent pipes attached to a wooden chest piece.

In 1851, when flexible tubing made of tree sap became available, Irish physician Arthur Leared invented the modern binaural stethoscope. Soon after, in 1852, George Cammann refined the design for commercial production and distribution. The new stethoscope used rubber tubing to connect a headset and a chest piece. The head set had two ivory earpieces that were inserted into the physician's ears. The earpieces were connected by metal tubes made of silver and held together at a hinge joint. Two silk-covered tubes met at a hollow ball, which amplified the sound and was attached to the trumpet-shaped chest piece. Cammann did not file a patent for his stethoscope because he wanted it to be freely available for physicians' use. The Cammann stethoscope remained in common use for almost 100 years.

In 1961, Harvard professor and cardiologist David Lippmann invented the combination, or two-sided, stethoscope in use today. The chest piece bell had an open side for hearing low-pitched sounds. The other side was enclosed with a stiff diaphragm that filtered out low-pitched sounds. The firmer tubing transmitted sound more clearly, and the entire stethoscope was lightweight and convenient to carry. Lippmann sold his patent to the 3M Company, which continued to improve its acoustics and capabilities. Modern stethoscopes have tunable diaphragms, ambient noise reduction, and Bluetooth connectivity.

Lynda C. Titterington

See also *Vol. 3, Sec. 1: Magnetic Resonance Imaging (MRI)*

Further Reading

- Aitken, W., and M. Clymer. 1872. *The Science and Practice of Medicine*, vol. 2. Philadelphia: Lindsay and Blakiston.
- Blaufox, M. D. 1999. *An Ear to the Chest: An Illustrated History of the Evolution of the Stethoscope*. New York: The Parthenon Publishing Group.
- Littman, D. 1965. Littman Stethoscope. U.S. Patent 3,276,536 A. <https://www.google.com/patents/US3276536>, accessed August 29, 2018.
- Mohan, Prad. 2014. *Stethoscopes: Rene Laennec to David Littman*. n.p.: Creative Commons.

Stockyards

Stockyards are areas that contain multiple pens and sheds used to harbor livestock for the purpose of slaughtering for meat or selling. These places generally hold animals such as pigs and cows. After months of feeding, these animals are transported to a slaughterhouse, killed, and butchered. The stockyard is a complementary service to the packaging and slaughterhouse industries. In some places, the stockyard and slaughterhouse are nearby each other. Recently, stockyards have received a bad reputation for animal cruelty, poor sanitation, and generally poor health of the animals. Many people see them as unsustainable, environmentally unfriendly, and blights on communities.

There was a proliferation of American stockyards in the 19th century in response to westward expansion and railroads. Westward expansion and the decimation of Native American peoples allowed for increased cattle-grazing on private and public lands. Railroads provided a quick and affordable method of getting cattle from thinly populated Western territories and states to Eastern cities. Stockyards sprang up in these cities to hold and fatten Western beef before slaughter.

In 1844, a Cincinnati stockyard began selling meat outside the United States, creating an international market for American beef and pork. In 1844, it was reported that 26 Cincinnati firms provided over \$2.8 million in meat. Stockyards became an economic lifeline for some cities. The industry has grown a tremendous amount, especially since the American Civil War (1861–1865). Cities like Chicago became pork

capitals. Stockyards were often adjacent to railways and slaughterhouses and were able to sell outside their regions.

There was little public interest in the well-being of livestock in the 1800s and almost no state or federal regulations on it. In the 1870s and 1880s, there were improvements in mobile refrigeration that caused distribution systems to expand across states and dominate markets. Regulation of the market began during these times because these expanding industries violated the Sherman Antitrust Act.

During the Great Depression, meat consumption declined as Americans could not afford to buy it. With World War II, this changed, and stockyards and slaughterhouses found their business booming. After the war, livestock production increased exponentially. The U.S. Department of Agriculture (USDA) began to place letter grades on meat based on the animals' diets. Stores began to demand only meat that met USDA standards. Stockyard companies began to hire nutritionists and veterinarians to meet the standards for Prime and Choice beef. More regulation, such as that banning harmful feed and the introduction of the Wholesome Meat Act (1967) to regulate animal hygiene, was introduced.

The stockyard industry is a vital part of the American economy. Along with becoming a global industry that sustained cities, much innovation came with it. For example, the use of preservation was key for the packaging industry. Preservatives and salt were added to meat to increase usability. In addition, refrigerated trucks to transport meat were developed. Refrigeration was implemented in other transportation systems such as trains and boats.

Nonetheless, environmental experts and animal rights activists have made a strong case for ending the stockyard system. Vivid representations of abused and sick animals have turned some of the public against this type of meat production and toward sustainable, cruelty-free meat. One problem that needs to be addressed is the pollution that comes directly from stockyards. Stockyards also contribute to the methane gas problem, and methane remediation systems are expensive. Moreover, animal scientists point to the fact that stockyard animals eat grain, mostly corn—both because grain fattens animals quickly and because corn, as a federally supported monoculture, is cheap.

Cows are meant to eat grasses, not grain, and thus feedlot cows are unhealthy and unnatural, particularly given the massive amounts of antibiotics that must be fed to animals who live in such close proximity and in such unhygienic lots. Consumers now face a choice: consuming large amounts of readily available and cheap meat that is bad for the world they live in, bad for themselves, and bad for the animals; or consuming less meat from sustainable, cruelty-free, ethically raised, grass-fed animals.

Michael Sandoval

See also *Vol. 1, Sec. 2: Three-Piece Iron Plow; Vol. 1, Sec. 3: Combine Harvester; Deere, John and Deere and Company; Polished Steel Plow; Vol. 3, Sec. 2: Sustainable Agriculture*

Further Reading

- Niman, Nicolette Hahn. 2014. *Defending Beef: The Case for Sustainable Meat Production*. White River Junction, VT: Chelsea Green.
- Pacyga, Dominic. 2015. *Slaughterhouse: Chicago's Union Stock Yard and the World It Made*. Chicago: University of Chicago Press.

Primary Document: Photograph of Chicago's Union Stock Yards (1907)

The Union Stock Yards in Chicago, Illinois, seen here in 1907, created a clearinghouse for cattle all over the West and Midwest. These yards dominated the Chicago meatpacking district for over a century, beginning in 1865. Stockyards like these changed ranching, signaling a shift to the modern agribusiness, the factory farm approach to agriculture.



Source: Library of Congress.

Tape Measure

While there is no actual record of the first appearance of the tape measure, there is a record of who has improved it to what it is today. Tools of measurement were generally not portable before the creation of the tape measure. Historically, measuring implements were not flexible. However, measuring length with flexible material had been done before, such as with chains, rope, and strips of leather.

In 1864, William H. Bangs, a Connecticut inventor, filed a patent for a spring return pocket tape measure that functioned much like modern tape measures. It could be stopped at any point and had a button that caused the tape to spring back into the case.

In 1922, Hiram Farrand patented the convex tape measure, which became the standard shape for measuring tape. The convex shape allowed the tape to be spooled out in rigid form, making measuring much easier.

There is not much that can be improved about this product anymore. There are laser tools that judge distance and tape measures with digital screens that note the distance. The tape measure will not cease to exist, since it has applications that are unlikely to be replaced. Construction workers or those in the business of cutting wood use this technology constantly.

Michael Sandoval

See also *Vol. 2, Sec. 2: Scotch Tape*

Further Reading

Bedi, Dharty, et al. 2016. *Pocket Genius: Inventions*. New York: DK.

Taylor, Frederick (1856–1915)

Frederick Winslow Taylor, the “father” of scientific management, was an expert in efficiency. Critics of his day charged that “Taylorism” was an oppressive system that dehumanized workers. In spite of this, scientific management has been extremely influential.

Taylor was born in Germantown, Pennsylvania, on March 20, 1856. After a short apprenticeship in a small

machine shop, he took a full-time job at Midvale Steel Company in Philadelphia in 1883. At the same time, he enrolled at Stevens Institute of Technology in New Jersey, where he earned an engineering degree even though he never attended classes. His 12 years at Midvale were formative for him. He spent that time learning the different facets of the organization while he moved up the career ladder from gang boss, assistant foreman, foreman of the machine shop, master mechanic, chief draughtsman, to chief engineer. In fact, at Midvale, he developed the fundamentals of what later became known as “scientific management.”

At Midvale, Taylor became convinced that productivity was directly tied to the tools that were used to do a job and the techniques used to maintain those tools. His experiments led to the development of about 100 patented inventions that were in general use in factories by the early 1900s. His most notable innovation was the Taylor-White process for treating high-speed tools. Workers could cut through metal three times faster with treated tools. He received a gold medal for the Taylor-White process from the Paris Exposition of 1900.

Having improved the tools of the trade, Taylor turned his attention to the human aspect of labor. He was interested in finding a way to make humans more productive by reducing costs and increasing factory output. Based on his timed experiments at Midvale, Taylor developed and introduced ways to standardize work tasks. In 1898, Taylor took a job at a large steel company in Bethlehem, Pennsylvania, where he conducted his famous “time-and-motion” experiments and supervised the introduction of standardized work procedures. He concluded that productive workers engaged in timed, task-specific motions who were given the opportunity to earn 60 percent more wages would produce 380 percent more output.

After leaving Bethlehem, Taylor retired from factory work and devoted his time to consulting, lecturing, and writing. In 1905 and 1906, he served as president of the American Society of Mechanical Engineers. His most influential work was *The Principles of Scientific Management* (1911). Many business owners were attracted to scientific management in a desire to increase profits. On the other hand, many

labor leaders denounced scientific management, believing that it transformed human workers into nothing more than small cogs in a large industrial machine.

A high-profile strike brought on by resistance to the introduction of scientific management at a government arsenal led to a government investigation. Although the U.S. Congress did not mandate any changes pertaining to business practices, scientific management gained a bad reputation from the affair. Years later, motion pictures continued to promote a negative view of scientific management in the popular mind with iconic films like *Metropolis* (1927), the story of a futurist utopia only made possible by mistreating workers, and Charlie Chaplin's *Modern Times* (1936), which depicts human suffering caused by the efficiencies of modern industrialization.

Taylor, who genuinely believed that his principles were humane when applied correctly, was hurt by the negative view of his life's work, and he permanently withdrew from public life. He died of pneumonia in Philadelphia on March 21, 1915. In spite of criticism, the principles of scientific management were extremely influential.

Through the rest of the century, factory managers often promoted efficiency with the use of assembly-line-type work spaces where unskilled workers completed certain tasks within time limits. Educational leaders sought school efficiency by standardizing various aspects of the educational experience, including requiring standardized curricula and standardized testing. Many school administrators liked scientific management, because they believed that it promoted the most efficient use of available resources and encouraged accountability.

Rolando Avila

See also Vol. 2, Sec. 2: Assembly Line

Further Reading

Copley, Frank B. 1923. *Frederick W. Taylor, Father of Scientific Management*. New York: Harper and Bros.
Nelson, Daniel. 1980. *Frederick W. Taylor and the Rise of Scientific Management*. Madison: University of Wisconsin Press.

Tesla, Nikola (1856–1943)

Not many people recognized the man on the cover of *Time* magazine from July 20, 1931. He was an inventor and innovator who held over 250 patents worldwide and invented the method to power everything from small radios to our home appliances to huge factories: Nikola Tesla.

Tesla was born in Smiljan in the Austrian Empire (Croatia). His family was of Serbian descent. His father, Milutin Tesla (1819–1879), was an Eastern Orthodox priest. His mother, Djouka Mandic (1821–1892), was an inventor. She created tools and mechanical appliances to help with housework. She never learned to read or write, but she was clever.

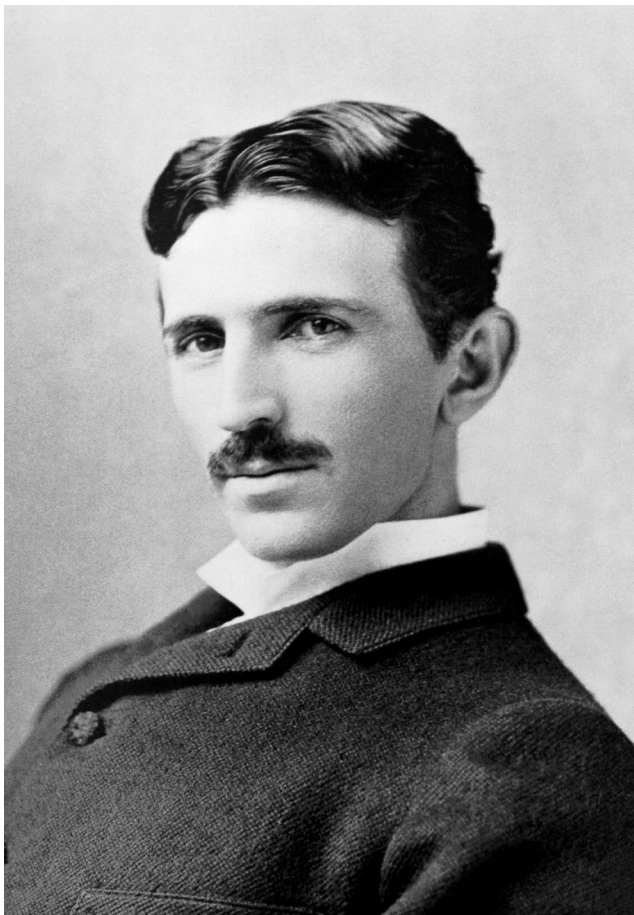
Tesla was a student at the Real Gymnasium at age 14. He studied electricity and experimented with batteries, induction coils, water turbines, and motors. Tesla studied engineering at the Austrian Polytechnic in Graz, Austria, in 1875 with a Military Frontier Authority Scholarship. He was a good student until his third year, when he became bored and frustrated with his studies. He started gambling. He never graduated.

He needed money, so he started an apprenticeship to become a teacher. Then a more technical job became available, but it was in Hungary, so Tesla moved to Budapest in 1881. He worked for the Hungarian government's Central Telegraph Office Engineering Department as a designer and draftsman. He didn't make much money, but he continued to experiment on his own with electricity and magnetism.

When the new American Telephone Exchange Company opened in Budapest, he took a job there as a mechanic and mathematician. He would take apart equipment to see how it worked and looked for ways to improve it.

Tesla went to Paris in 1882. He worked for the Continental Edison Company. Incandescent lights were being installed throughout Paris. Thomas Edison's company used direct current (current in which electrons flow in a single direction), known as DC, to deliver power. Central stations were built throughout the city that supplied power for lighting homes and city streets.

Tesla submitted a plan to improve the company's dynamos (generators or machines that convert



Best remembered for the “current wars” with Thomas Edison, Nikola Tesla was an innovative and iconoclastic inventor, engineer, and physicist. While he was largely forgotten in the decades after his death, Tesla’s reputation has more recently been transformed, making him a recurring trope in contemporary science fiction. (Library of Congress)

mechanical energy to electrical energy). He received no compensation. When he saw ways to improve a process, he did so.

Tesla was transferred to Strasbourg, France, on the border with Germany in 1883. He worked on his idea for an alternating current (AC) motor. Alternating current does not flow in just one direction; it periodically reverses direction several times per second.

Tesla emigrated to the United States in 1884. He worked for a short time for Edison Machine Works in New York City. He presented his idea for an alternating current motor to his employers, but it was not well received. Tesla was given the opportunity to redesign Edison’s DC machines if he found a way to improve

them. Tesla maintained he was offered additional money for doing so. The company disagreed. Company officials said Tesla was never offered additional money. There was no written agreement so Tesla quit.

Tesla opened his own lab, Tesla Electric Light & Manufacturing Company. His first patent (number 335,786) in 1886 was for an improved arc lamp. The lamp provided uniform light with minimal flickering. Tesla split 50-50 with investors any money made from the patent for his AC dynamo (U.S. Patent 359,748, “Dynamo-electric Machine,” 1887). He needed money to continue his work.

Tesla demonstrated the advantages of using alternating current at an American Institute of Electrical Engineers meeting. Alternating current of high voltage could be sent over small wires for long distances. A transformer would reduce the high voltage to whatever voltage was needed at a location. It could then be distributed to businesses, factories, or homes, or for streetlights. Electricity could be transported from a single distribution point for hundreds of miles. AC-generating stations could be larger and so more efficient. Transmission wires could be smaller, providing more savings. Tesla’s findings were confirmed by others at the meeting.

Tesla met with George Westinghouse in 1888 in Pittsburgh, Pennsylvania. Westinghouse was an engineer who had invented the railway air brake. He also founded an electric company. He saw the potential of AC over Edison’s DC. Westinghouse and Tesla came to an agreement: Westinghouse would buy Tesla’s patent(s) and pay Tesla royalties based on watt per hour of electricity produced. Westinghouse also agreed to pay at least part of any legal fees from lawsuits. He offered stock in Westinghouse’s company.

Tesla moved to Pittsburgh to work on the AC motor. He stayed for a year and returned to New York City in 1889. Tesla became a naturalized U.S. citizen in 1891.

The Nikola Tesla Company was founded in 1895 to fund and promote Tesla’s patents and inventions. Tesla continued to work on a variety of ideas, from developing x-rays, a radio, wireless communications, robotics, bladeless turbines, and radio remote control of boats and torpedoes. Tesla worked on an induction coil (a transformer that transforms low-voltage AC

current into high-voltage pulses). The coil was patented January 9, 1894 (number 512,340).

Tesla received honorary degrees Columbia and Yale Universities in 1894. He died in 1943 in New York City.

Linda Briley-Webb

See also Edison, Thomas

Further Reading

Asimov, Isaac. 1982. *Asimov's Biographical Encyclopedia of Science & Technology: The Lives & Achievements of 1510 Great Scientists from Ancient Times to the Present*. Garden City, NY: Doubleday.

Hakim, Joy. 2007. *The Story of Science: Einstein Adds a New Dimension*. New York: Smithsonian Books.

Seifer, Marc. 1998. *Wizard: The Life and Times of Nikola Tesla: Biography of a Genius*. New York: Kensington.

Ticker Tape

Ticker tape was created by Edward A. Calahan in 1867 and patented by the U.S. Patent Office on March 31, 1868, to go along with the stock ticker. The stock ticker was invented as a cheaper and more reliable means of printing indicators that traveled across electrical telegraph lines for the stock market in gold, merchandise, and other stocks from distant businesses and trades. Other inventions attempted to fill the need but were expensive and more prone to breaking.

The paper of the ticker tape was divided into two sections that would be printed on by two separate wheels of the stock ticker machine. The first wheel had the alphabet, while the second wheel had numbers and a few letters. With the two wheels working simultaneously, information on specific businesses by abbreviated names would be printed on the first strip, and their stock prices were printed on the second strip.

Before the general acceptance of the stock ticker and ticker tape, financial information was shared through handwritten letters. Sending letters was slow and gave investors old financial information on their investments. While shareholders were able to see the

prices of their investments, they did not receive up-to-date information of how prices were increasing or decreasing. Still, letters were a more personal way of exchanging information and allowed relationships to be developed among shareholders and brokers. On Broad Street, brokers hired boys to listen to and write down the changing prices on the stock market and sold the information to potential shareholders. While the boys could get changing prices out fairly quickly, the prices on the ground floor were changing constantly, and it was nearly impossible to keep up by hand. The main problems with the use of handwritten notes on prices were the misinterpretation of information, losing or misplacing of said notes, and the potential for falsification.

The New York Stock Exchange made a contract for Calahan's stock ticker made him its sole supplier. By 1882, over 1,000 tickers were in New York City. With the introduction of the ticker to the stock market, the plan of the ground floor was changed. Brokers were able to stay connected to it with up-to-date changes in prices without the need to hire messenger boys, and there was a lower possibility of forgery.

Ticker tape was replaced in the stock market in the mid-1900s with the invention of computers and televisions. Though the electronic stock ticker was introduced in 1960 and is still in use today, it is not essential. It is kept more as a nostalgic representative of the stock market. However, ticker tape is still seen today in ticker tape parades in New York City. It takes the form of confetti that rains down on everyone below.

Carina J. Ariss

See also *Vol. 1, Sec. 3: Telegraph*

Further Reading

Calahan, Edward A. 1868. Telegraphic Indicator. U.S. Patent 76,157, filed March 23, 1868, and issued March 31, 1868.

Preda, Alex. 2006. "Socio-Technical Agency in Financial Markets: The Case of the Stock Ticker." *Social Studies of Science* 36, no. 5: 753–82.

Sussman, Mark. 1995. "Celebrating the New World Order—Festival and War in New York." *The Drama Review* 39, no. 2: 147–75.

Tom Thumb Locomotive

The *Tom Thumb* locomotive was created by Peter Cooper in 1829 for the Baltimore and Ohio Railroad Company to show that steam engines were more efficient than the widely used horse-drawn railcars. The *Tom Thumb* was the first steam engine to be developed on American soil. The Baltimore and Ohio Railroad, created by Ellicott's Mills, had curves to go around rocks, which were considered impassable for locomotives. Therefore, horse-drawn cars were used instead. The ill-conceived line of the railroad was probably why the company went bankrupt. To fix this bankruptcy dilemma, Cooper wished to prove that steam locomotives were able to travel the railroad and curves better and faster than horse-drawn cars. He entered his in a race against a horse-drawn car belonging to Stockton and Stokes's stage cars. The *Tom Thumb* locomotive was in the lead, passing the curves at 15 miles per hour, until a belt slipped from the fan and could not be fixed fast enough before the horse gained ground and won the race. However, even with the loss, the Baltimore and Ohio Railroad Company offered a reward of \$500 to other designers who could create a locomotive able to pull 15 tons at 15 miles per hour.

The *Tom Thumb* model was smaller than other locomotives. It weighed less than one ton, with the cylinders being 3.5 inches in diameter. The spur wheel on the crankshaft had a pinion to aid in increased speeds. The wheels were 2.5 feet in diameter. The main fuel source consisted of anthracite coal. Peter Cooper did not have any diagrams or notes on developing the *Tom Thumb*, but Benjamin H. Latrobe provided sketches from his recollections of the model.

A functioning replica of the *Tom Thumb* locomotive is at the Baltimore and Ohio Railroad Museum to use in demonstrations and exhibitions. The replica was initially constructed for the Pageant of Locomotives at the Fair of the Iron Horse held in 1927. The replica differs from the original in that it weighs five tons instead of one, with various other changes.

The significance of the *Tom Thumb* as the first steam engine to attempt the impassable railroad of the Baltimore and Ohio Railroad Company opened the door for other inventors to step up. After Baltimore and Ohio accepted the *Tom Thumb* model, the horse-drawn cars were replaced by steam-powered cars in 1831.

Carina J. Ariss

See also Railroad Refrigerator Car; Railroad Sleeping Car and Pullman Car; *Vol. 1, Sec. 3: Pullman*, George Mortimer; Railroads

Further Reading

"Model of 'Tom Thumb' Locomotive." 1830. Washington, D.C.: Smithsonian Institution. http://amhistory.si.edu/onthemove/collection/object_882.html, accessed August 29, 2018.

New York Academy of Sciences. 1881. *Transactions of the New York Academy of Sciences*. New York: New York Academy of Sciences.

Rakeman, Carl. 1830. The Iron Horse Wins. From the U.S. Department of Transportation, Federal Highway Administration, <https://www.fhwa.dot.gov/rakeman/1830.htm>, accessed August 29, 2018.

Sagle, Lawrence W. 1948. "The Tom Thumb: Little Known Facts About First Locomotive Built in America Slowly Come to Light." *The Railway and Locomotive Historical Society Bulletin* 73: 46–53.

Primary Document: John Latrobe's Description of the *Tom Thumb* Locomotive (1830)

In 1830, John Latrobe, a lawyer for the Baltimore and Ohio Railroad, wrote about the excitement of seeing the first American-built steam locomotive, the Tom Thumb. Latrobe quite correctly predicted the potential impact of railways on travel and national expansion.

The First American Locomotive, Peter Cooper's "Tom Thumb" by John H.B. Latrobe

BY JOHN H. B. LATROBE

When steam made its appearance on the Liverpool and Manchester Railroad it attracted great attention here. But there was this difficulty about introducing an English engine on an American road. An English road was virtually a straight road. An American road had curves sometimes of as small radius as two hundred feet. For a brief season it was believed that this

feature of the early American roads would prevent the use of locomotive engines. The contrary was demonstrated by a gentleman still living in an active and ripe old age, honored and beloved, distinguished for his private worth and for his public benefactions; one of those to whom wealth seems to have been granted by Providence that men might know how wealth could be used to benefit one's fellow creatures.

The speaker refers to Mr. Peter Cooper of New York. Mr. Cooper was satisfied that steam might be adapted to the curved roads which he saw would be built in the United States; and he came to Baltimore, which then possessed the only one on which he could experiment, to vindicate his belief. He had another idea, which was, that the crank could be dispensed with in the change from a reciprocating to a rotary motion: and he built an engine to demonstrate both articles of his faith. The machine was not larger than the hand-cars used by workmen to transfer themselves from place to place; and as the speaker now recalls its appearance, the only wonder is that so apparently insignificant a contrivance should ever have been regarded as competent to the smallest results. But Mr. Cooper was wiser than many of the wisest around him. His engine could not have weighed, a ton; but he saw in it a principle which the forty-ton engines of to-day have but served to develop and demonstrate.

The boiler of Mr. Cooper's engine was not as large as the kitchen boiler attached to many a range in modern mansions. It was of about the same diameter, but not much more than half as high. It stood upright in the car, and was filled, above the furnace, which occupied the lower section, with vertical tubes. The cylinder was but three and a half inches in diameter, and speed was gotten up by gearing. No natural draft could have been sufficient to keep up steam in so small a boiler; and Mr. Cooper used therefore a blowing apparatus, driven by a drum attached to one of the car wheels, over which passed a cord that in its turn worked a pulley on the shaft of the blower. . . .

Mr. Cooper's success was such as to induce him to try a trip to Ellicott's Mills; and an open car, the first used upon the road, already mentioned, having been attached to his engine, and filled with the directors and some friends, the Speaker among the rest, the first journey by steam in America was commenced. The trip was most interesting. The curves were passed without difficulty at a speed of fifteen miles an hour;

the grades were ascended with comparative ease; the day was fine, the company in the highest spirits, and some excited gentlemen of the party pulled out memorandum books, and when at the highest speed, which was eighteen miles an hour, wrote their names and some connected sentences, to prove that even at that great velocity it was possible to do so. The return trip from the Mills—a distance of thirteen miles—was made in fifty-seven minutes. This was in the summer of 1830.

But the triumph of this Tom Thumb engine was not altogether without a drawback. The great stage proprietors of the day were Stockton & Stokes; and on this occasion a gallant gray of great beauty and power was driven by them from town, attached to another car on the second track—for the company had begun by making two tracks to the Mills—and met the engine at the Relay House on its way back. From this point it was determined to have a race home; and, the start being even, away went horse and engine, the snort of the one and the puff of the other keeping time and time. At first the gray had the best of it, for *his* steam would be applied to the greatest advantage on the instant, while the engine had to wait until the rotation of the wheels set the blower to work. The horse was perhaps a quarter of a mile ahead when the safety-valve of the engine lifted and the thin blue vapor issuing from it showed an excess of steam. The blower whistled, the steam blew off in vapory clouds, the pace increased, the passengers shouted, the engine gained on the horse, soon it lapped him—the silk was plied—the race was neck and neck, nose and nose—then the engine passed the horse, and a great hurrah hailed the victory.

But it was not repeated; for just at this time, when the gray's master was about giving up, the band which drove the pulley, which drove the blower, slipped from the drum, the safety-valve ceased to scream, and the engine for want of breath began to wheeze and pant. In vain Mr. Cooper, who was his own engineman and fireman, lacerated his hands in attempting to replace the band upon the wheel: in vain he tried to urge the fire with light wood; the horse gained on the machine, and passed it; and altho the band was presently replaced, and steam again did its best, the horse was too far ahead to be overtaken, and came in the winner of the race. But the real victory was with Mr. Cooper, notwithstanding. He had held fast to the faith

that was in him, and had demonstrated its truth beyond the peradventure. All honor to his name. . . .

In the Musée d'Artillerie at Paris there are preserved old cannon, contemporary almost with Crecy and Poitiers. In some great museum of internal improvement, and some such will at some future day be gotten up, Mr. Peter Cooper's boiler should hold an equally prominent and far more honored place; for while the old weapons of destruction were ministers

of man's wrath, the contrivance we have described was one of the most potential instruments in making available, in America, that vast system which unites remote peoples and promotes that peace on earth and good will to men which angels have proclaimed.

Source: Latrobe, John H. B. 1868. *The Baltimore and Ohio Railroad: Personal Recollections*. Baltimore: Sun Printing Establishment.

Track-Type Tractor

Benjamin Holt was the founder and president of the Holt Manufacturing Company of Stockton in 1883. The track-type tractor, also known as the "Caterpillar," was first field-tested in 1904 and later sold in 1906 as a steam engine. The name "caterpillar" was coined by a reporter who witnessed the tractor at work during a demonstration in 1905. The innovative tracks of the tractor replaced the regular rear wheels of a steam-powered traction engine to more easily move through the deep and muddy terrain of Stockton, California. Once Holt converted the engine from steam to gasoline in 1908, subsequent sales in 1909 increased higher than in any previous year. With the increased success, Holt patented the traction-type tractor in 1913. By the 1920s, the caterpillar was introduced into construction with experiments using different "heads." Now, bulldozer heads are standard on some models of the caterpillar.

The wheels of previous tractor models would sink into the deep mud of Stockton during fieldwork. To counteract this setback, even bigger wheels were used. Some were as massive as 45 feet wide and 12 feet in diameter. These wheel sizes quickly became unrealistic to work with, and Holt developed the idea of a continuous track as a replacement. The tracks were constructed of 3-inch × 4-inch wooden slats bolted to an endless chain. The chain was 9 feet × 2 feet. The belt track was powered directly and more evenly distributed the weight of the tractor. While the tractor was initially invented to aid in farming, it later moved into the construction industry with advanced models still seen today.

During World War I, the caterpillars were used instead of livestock for towing the Allied forces' supplies. Earlier war vehicles, such as the armored car, needed flat terrain to travel. This was not always available during the war, and all-terrain armored vehicles were in high demand. With the efficiency of the tracks, the caterpillar inspired the invention of tanks, which changed warfare forever.

For the future, it can be expected that tractors will conduct fieldwork automatically, without the need for a human driver. With technology in agriculture heading to unmanned vehicles, efficiency will increase and continual work can be done without breaks except for refueling and repairs. This will allow for increased crop yields to feed continued human population growth.

Carina J. Ariss

See also *Vol. 1, Sec. 2: Steam Tractor*

Further Reading

- Hariss, Stephanie. 2006. "A Century of Equipment." *Roads & Bridges* 44, no. 4: 18–21.
- Holt, Benjamin. 1913. Traction Engine. U.S. Patent 1,076,578, filed February 18, 1913, and issued October 21, 1913.
- "Holt Cat Celebrates Tractor's 100th Anniversary." 2004. RER: Rental Equipment Register. June 1. <http://rermag.com/mag/holt-cat-celebrates-tractors-100th-anniversary>, accessed August 29, 2018.
- "The Main Battle Tank." 2014. *Military Technology* 28, no. 6: 100–107.
- Smith, Ron. 2016. "Driverless Tractors: Technology Will Guide Next Generation of Farmers." *Southwest Farm Press* 43, no. 23: 1–7.

Transcontinental Railroad

The first locomotive rail train to travel from the Eastern seaboard to the Western coastline of the United States was known as the Transcontinental Railroad. The inception of the Transcontinental Railroad was a monumental venture not thought possible to achieve in its day. Not until the advent of electric wiring throughout the United States would there be such an impact on Americans socially and economically. Spanning across 1,000 miles over the most difficult terrain in the country, when finished, it surpassed expectations regarding moving goods and services, making a relative few staggeringly wealthy. The ambitious effort was fraught with scandal from the first moments of inception to the final strike of the last golden spike in Promontory, Utah, in 1869.

Financed by the U.S. government under the Pacific Railroad Act and with full support of President Abraham Lincoln, Congress approved the Union Pacific Railroad, a corporation chartered by the federal government. Approved under wartime circumstances during the American Civil War, the act was as much a business enterprise as a booster to Union nationalism in a deeply divided country.

Up until this time, overland travel to the western end of America was fraught with peril, with no guarantee of safety. Options for transportation included stagecoaches and local, short-run railway lines in steam cars. Depending on the final destination, travel often included both rail and stagecoaches to complete; frequent transfers between trains compounded the trouble of an often arduous journey. Those on a migration path to the West chose wagon trains, which were used primarily in the western expansion across the country. Also referred to as “prairie schooners,” they were able enough to carry goods, supplies, and shelter, allowing a family to subsist on the trail with other wagons. Others chose ocean travel by way of South America, a six-month journey. Either route was a dangerous enterprise with no assurance of reaching the final destination.

Early efforts to harness the power of mass transportation into an efficient system of economy, safety, and expediency played out in Europe and later, America, all with varying degrees of success. Oliver Evans

(1755–1819) applied for a U.S. patent in 1787 for the right to construct vehicles powered by steam for use both on road and rail networks. In 1804, Richard Trevithick’s (1771–1833) efforts paid off with England’s first engine-powered land vehicle resembling a potbellied stove on wheels with smokestack, similar to Evans’s patent in America. Trevithick may have been inspired by Evans’s work. Improvements over time continued, leading to the first railroad line in the world built in 1825 by John Blenkinsop (1783–1831).

Railroads and railroading had been a presence in American towns decades before the construction of the Transcontinental Railroad. The Quincy Granite Road, one of the earliest U.S. railroads, opened in 1830. The Baltimore and Ohio Railroad, 14 miles in length, opened in 1830 and by 1831 had ceased its horse-drawn operation, converting to locomotives. By 1836, there were over a thousand miles of railroad in the United States. Just over a decade later over, 5,200 miles of railroad track had been laid. In the 1850s, New York was host to the longest stretch of railroad in the world at over 400 miles. By 1852, over 10,000 miles of steel track sped goods, passengers, and services, with thousands more at the ready along the eastern half of the United States.

Once railways transitioned from horse-drawn trains to locomotives, there was no turning back. The first railroad passenger train’s appearance was a series of stagecoach-looking cars for passengers pulled on wheels powered by a wood-burning engine car with a tall chimney and an open-air wagon placed in between for hauling freight or barrels. Both European and American railways were similar in construction: wooden timbers laid flat upon the earthen ground, flanked by strip iron fastened together by spikes. Later, granite ties minimized derailments caused by loose rails.

Efforts to gain support for a railroad spanning the American continent began during the tenure of Abraham Lincoln’s presidency. Land surveys commenced to determine the safest, most direct routes along which to lay track. Legislation from Congress stipulated that railroad lines be divided between two competing companies. The Central Pacific, begun in California by five businessmen from Sacramento, was headed by Collis Potter Huntington, forming a partnership that would take the Central Pacific railroad east.

Simultaneously, the Union Pacific, originating out of Council Bluffs, Iowa, was headed by director Sidney Dillon and utilized contractors and brothers Jack and Daniel Casement. Jack served during the American Civil War and could therefore apply both acquired leadership from battle and railroad experience in laying over 1,087 miles of track to the West. Both the Central and the Union Pacific had financial incentives and subsidies, such as loans and grants for land, to implement the 1862 congressional directives as quickly as possible. Whichever side could gain the most ground would (in theory) reap the greatest financial gain for its investors.

Both the Union Pacific and Central Pacific experienced delays, setbacks, and conflict almost from the beginning. Acquiring a labor force equal to the monumental task of not only laying track but also navigating environmental extremes of snow and heat, Indian uprisings, and disease proved daunting. Relying upon his military background, Jack Casement rallied former soldiers from both Union and Confederate sides as far away as Chicago and New York. All told, over 1,000 men—Irish, Southerners, and Yankees alike, along with transients and fugitives from the law—provided the muscle for the Union Pacific. The Central Pacific labor force was composed from an unlikely source: thousands of Chinese laborers turned away from the gold fields of California. Immigrating to the United States during the California Gold Rush in 1848, these people were no strangers to hard work and were sought after as a reliable and cheap source of labor.

During the five years it took to finish the Transcontinental Railroad, remote sections of America's countryside morphed as each strip of track was laid, advancing upward of eight miles a day. Mountains were dynamited to give right-of-way to the locomotives. Temporary towns sprang up overnight as thousands of laborers needed shelter, food, and water and, just as quickly, they disappeared, leaving in their wake a forever altered landscape.

Corruption plagued both sides of the massive undertaking as greed dominated the enormous enterprise, fueled by realization that more money was made with building contracts before completion than with the final finished product. Though a fairly common practice in American railroad construction, it wasn't

until the *Crédit Mobilier* scandal uncovered a system of bribes reaching all the way to Washington, D.C. that the *Crédit Mobilier of America* was set up to oversee the financial and construction aspects of the Union Pacific Railroad. What it did in reality was severely deplete the financial resources of the railroad while lining the coffers of its trustees and participants.

The advent of the railroad left an indelible print on the lives of Americans of European, Asian, and African descent as well as Native American tribes. In a broader sense, the future economic life of those working in the railroad industry expanded a labor relations system that included union representation and organization. These workers were skilled, operating very costly locomotives, and not easily replaced; this empowered them to call a strike when working conditions proved exceptionally difficult. This was the impetus for future labor relations in the emerging corporate economy evolving in Victorian America.

The vibrant life of the American plains and of its native people was forever erased as the U.S. federal government took the land from Native people and gave it to the railroads. The Cheyenne and Comanche resisted the encroachment by whites, resulting in a federal military presence with forts built to ensure completion of the railroad. For the Chinese population post-construction, the Transcontinental Railroad no longer needed their work, so the newly unemployed men now competed for other work. They were, however, often thwarted by racial bigotry as whites feared that the Chinese immigrants would undercut wages. But for those who migrated and settled across the plains by choice, the advance of the railroad signaled a lifeline, creating and connecting communities, bringing more people to once-isolated areas.

Cynthia J. Parker

See also Vol. 1, Sec. 3: Conestoga Wagon

Further Reading

Ambrose, Stephen E. 2000. *Nothing Like it in the World: The Men Who Built the Transcontinental Railroad, 1863–1869*. New York: Simon & Schuster.

Cadbury, Deborah. 2003. *Dreams of Iron and Steel: Seven Wonders of the Nineteenth Century, from*

the Building of the London Sewers to the Panama Canal. New York: Fourth Estate.

Gordon, John Steele. 2004. *An Empire of Wealth: The Epic History of American Economic Power*. New York: HarperCollins.

Kirby, Richard Shelton, Sidney Withington, Arthur Burr Darling, and Frederick Gridley Kilgour. 1990. *Engineering in History*. New York: Dover.

Porter, Glenn. 1973. *The Rise of Big Business, 1860–1920*. Chicago: Harlan Davidson.

Twine Self-Binding Harvester

The twine self-binding harvester was created to improve and enhance the conventional harvester. The difference between this harvester and other self-binding harvesters was that it used twine instead of wire to bind grain. The purpose of this improvement was to carry grain as it was cut by the harvester and deliver it in a continuous flow. While delivering the grain, it would keep the straw in a straight condition as well as in the right direction in relation to the binding device, even if the machine was traveling on flat or uneven ground. It also delivered the grain differently depending on whether the grain was long straw or short straw. This improvement operated as an intermediate attachment between a harvester and grain binder.

There are many different types of self-binding harvesters, but as for the twine self-binding harvester, its creation is credited to Marquis L. Gorham in the 1870s. The patent was issued on March 16, 1875. Gorham's intention was to improve upon Cyrus H. McCormick's wire self-binding harvester of 1872. To do that, Gorham invented an attachment that would be added onto self-binding harvesters.

Others improved upon Gorham's invention and incorporated it into newer harvesters. Examples include Appleby & Co., Backer Co., and Harvester Pridemore as well as Cyrus H. McCormick. McCormick would create his own self-binding harvester in 1881—a low-down self-binding harvester—and a steel self-binding harvester in 1892.

Marquis L. Gorham's twine self-binding harvester attachment was influential on agriculture, moving it toward more efficient and effective technologies that

would automate or remove the need for human interaction. Tasks like bundling, collecting, and tying were phased out of the harvesting process, and eventually, human interaction was removed completely. Twine was much cheaper, more versatile, easier to cut, and easier to dispose of. Marquis L. Gorham's twine self-binding harvester was a stepping-stone in the innovation of agricultural technology and led to the development of more automated harvesters.

Randy Pham

See also *Vol. 1, Sec. 3*: Combine Harvester; McCormick, Cyrus; Mechanical Reaper

Further Reading

Creighton, Jeff. 1996. *Combines & Harvesters: A Photographic History*. Osceola, WI: Motorbook International.

Typewriter and QWERTY

Three American men patented the typewriter in 1868. The typewriter would allow more individuals to produce papers, novels, research, and business documents quickly. The typewriter was not only revolutionary at its inception, but it paved the way for future inventions, including the QWERTY keyboard layout, which has become the standard for almost all alpha keyboards.

In the 1860s, Christopher Latham Sholes, Carlos Glidden, and Samuel W. Soule worked together to create the first typewriter. It was patented on June 23, 1868. The first typewriter was unlike other typewriters to come, largely because of the layout of its keys. Unlike later typewriters, it did not have a key dedicated to every letter of the alphabet. Instead, the layout of the keys was like that of a piano's keyboard. It was very limited in its capabilities and, in the end, was unable to type every letter in the alphabet. Sholes, Glidden, and Soule patented an improved model of the typewriter soon after. This machine was much more usable.

The newer model had a key dedicated to each individual letter of the alphabet as well as keys for numbers. The layout had two rows: the top row was for

odd numbers and the second half of the alphabet, while the bottom row was for even numbers and the first half of the alphabet. Even though this model was a clear improvement over its predecessor, it was still horribly inefficient, and its letters were only uppercase.

In the 1870s, the typewriter was refined and improved. There were some modifications to the overall design of the typewriter, but the most frequent changes were still focused on the format and layout of the keys. In 1878, Sholes patented his most influential version of the typewriter, adding the QWERTY system designed to improve typing ease. Sholes did this because of all the complaints he had received about how inefficient the key placement was. He redesigned the keyboard layout so that the most commonly used letters were finger close, while the least used letters were farther away. It took nearly a decade for Sholes to create the most influential keyboard layout—one we still use today.

Sholes's contributions to the typewriter were extremely influential on future technology. Computers use the QWERTY keyboard format, as do cell phones, tablets, and more. Even touch screen keyboards use the QWERTY system, in part because it is now universally recognized.

Randy Pham

See also *Vol. 3, Sec. 1:* IBM 360 Computer; *Vol. 3, Sec. 2:* Computer/Information Technology; IBM Personal Computer; *Vol. 3, Sec. 3:* e-Book and e-Reader

Further Reading

Allan, Tony. 2015. *Typewriter: The History, the Machines*. New York: Shelter Harbor Press.

Velocipede

“Velocipede” is a term that describes a human-powered land vehicle with two or more wheels. It has managed to become synonymous for the bicycle. It was invented by Karl von Drais, a German inventor, who originally called it the *Laufmaschine* (running machine). It was also called the “dandy horse.” Karl von Drais first rode it on June 12, 1817. It took 40



A forerunner to the modern bicycle, velocipedes, also called “bone shakers” because of their uncomfortable ride, enjoyed wide popularity in the late 1800s. Like tricycles, their pedals were attached to the front axel. (Library of Congress)

years for the term “velocipede” to be used in more generic ways.

Some of the early velocipedes have designs with as little as one wheel and as many as five. The ones with two wheels had pedals near the front wheel, while those with more wheels had to use levers to steer the back.

It was not until the 1860s that the first pedal-equipped bicycle was developed by the Olivier brothers, Pierre Michaux, and Pierre Lallement. The Olivier brothers are considered the first people to recognize the commercial potential of the bicycle. Pierre Michaux was a blacksmith in the 19th century who added pedals to the front wheels of the velocipede. He began building bicycles with pedals in the early 1860s, and his company sold them on a much larger scale than any other. His son, Pierre Lallement, is credited

for making the first true bicycle; he added a rotary crank mechanism and pedals that attached to the front wheel. The Michaux Company was the first company to mass-produce the velocipede and did so from 1857 to 1871.

People called these machines “boneshakers” because the tires of the velocipede were mostly of iron and made it uncomfortable to ride on cobblestone roads. Velocipedes became more popular for indoor riding in “velodromes,” which are similar to roller-skating rinks.

It was not until the 1870s that all-metal velocipedes were developed. It was also realized that larger front wheels meant farther travel with each rotation of the pedals. Then, solid rubber tires brought much smoother rides. It was this type of velocipede that was first called a “bicycle.”

Alicia L. Garcia

See also *Vol. 1, Sec. 2:* Amphibious Steam Vehicle; *Vol. 3, Sec. 1:* Electric Car

Further Reading

Ambrose, Tom. 2013. *The History of Cycling in Fifty Bikes: From the Velocipede to the Pinarello: The Bicycles that Have Shaped the World*. New York City: Rodale Books.

Wiseman, Laura. 2017. *Velocipede*. Nacogdoches, TX: Stephen F. Austin University Press.

Vending Machine

Vending machines are automated machines that dispense anything from snacks, beverages, tobacco, alcohol, and birth control products (including condoms) to lottery tickets. Though, typically, vending machines accepted coins or paper money, many now accept credit cards. American scientist and inventor Thomas Adams developed the first American vending machines in 1888. His American Chicle Company also invented chewing gum. “Tutti Frutti” and “Spearmint” are among his most famous gum flavors. Adams’s invention of chewing gum laid the foundation for his innovation of the vending machine. The chewing gums “Black Jack” and “Tutti Frutti” were his first products to be sold in

vending machines. Thomas Adams was not the inventor of the vending machine; many had already been created in Europe in the early 1880s. However, Adams popularized vending technology in the United States.

Adams was trying to manufacture rubber tires by transforming chicle into synthetic rubber when he accidentally dropped a piece of rubber into his mouth and was fascinated by its consistency. He added flavor to the gum and named it Chiclets—a gum still marketed today. His American Chicle Company was the most successful gum company in the 19th century, and it became a monopoly in 1899 when it combined with the six largest gum manufacturers in the United States and Canada.

Adams’s positioning of the vending machines turned out to have a significant impact on the success of his business. He placed his first vending machines in busy New York City subway stations, where consumers could easily purchase chewing gum for a penny while they waited for their trains. Vending machines, which did not require a salesperson, were something new and popular in the United States back then. Another reason that the vending machine was successful was the rising popularity of chewing gum, since it was easy to chew in public and very inexpensive. The fact that gum did not deteriorate like other candy made it a perfect choice to be sold in vending machines. Other products, such as chocolate bars, were simply not suitable for hot weather conditions.

Compared to the vending machines we know today, Adams’s first vending machines were very simple and functioned purely mechanically. Today’s machines use electronics and multiple motors for dispensing a variety of products. His had a coin slot, a compartment where the product was supplied, and levers that activated its mechanism. Some even had animated figures for entertainment purposes. Many vending machines often did not work as expected, and their simple system made it easy to trick the machines. A well-developed coin-detection mechanism simply did not exist, which made it possible for customers to pay with any coin they had handy. Some customers even attached a string to a coin to pull it back out of the machine once the gum had been supplied. This, however, did not influence the success of the machines.

Over the years, more and more product variety was added to vending machines all over the world. In the 1930s, sodas like Coke and Pepsi were offered for the first time. Postcard-vending machines enjoyed a brief period of popularity, as did machines that dispensed small toys. In the late 20th and early 21st centuries, vending machines have been used to distribute items as varied as books and fishing bait. In the 1950s and 1960s, a person could buy life insurance from a vending machine, as well as molded plastic figurines. In the 2010s, marijuana became available through vending machines in states where the drug is legal.

Besides changes in product variety, vending machine technology also improved throughout the years and is in fact still improving. Support for accepting bills rather than coins made the customer experience more flexible. Between 2011 and 2013, retailers added the feature of using a credit card and even smartphones as payment options. Vending machines continue to be popular food-dispensing machines and can be found in places from school campuses to recreation parks.

Patrick Ketterer

See also Food Preservation; *Vol. 2, Sec. 2: Gumball Machine*

Further Reading

Salyers, Christopher D. 2010. *Vending Machines*. New York: Mark Batty.

Segrave, Kerry. 2015. *Chewing Gum in America, 1850–1920: The Rise of an Industry*. Jefferson, NC: McFarland.

Vibrator

The vibrator is a mechanized device used primarily for sexual pleasure, employed most often but not exclusively by women. Vibrators are designed in several varieties, including for clitoral, transvaginal, or rectal stimulation, or some combination thereof. Some models, such as the Hitachi Magic Wand (the number-one selling brand in the United States), are nominally intended for body spot-massaging. Since its development in the 1870s, the vibrator has evolved from a

physician's instrument to a consumer health panacea and finally to a recreational sex toy.

From antiquity into the early 20th century, physicians routinely masturbated their female patients. Doctors administered manual genital massages to women suffering from nervous disorders such as hysteria, nymphomania, or neurasthenia. Many of these conditions were ambiguously defined and today might be diagnosed as anything from anxiety to sexual frustration. This treatment reflected an androcentric model of sexuality that dismissed the female capacity for pleasure and reduced sex to two steps: penetration and male orgasm. Because this normative framework did not consistently satisfy the supposed aberrant functioning of women's sexual desire, relieving these "disorders" fell within the medical realm. Physicians sometimes instructed midwives or husbands in pelvic massage but usually performed the task themselves.

The 18th-century advent of steam and electrical power fundamentally changed the world. Steam engines and electricity allowed humans to travel and thrive in unprecedented numbers. They also introduced novel orgasm-inducing techniques and eventually inspired the first vibrator models. Some inventive physicians sent hysterical patients on locomotive trips over rough track to induce orgasm. Contemporary medical literature noted similar effects from horseback riding, operating foot-powered sewing machines, and, by the late 19th century, bicycle pedaling. Though many questioned such unorthodox practices, medical professionals understood the industrial-era logic of mechanizing labor.

By the second half of the 19th century, some doctors were experimenting with electric hydrotherapies, or douches containing an electrical current. Other devices included rubber-handled metal rods or rollers warmed by electrical current. Based on the observed efficacy of electric and vibratory stimulation, in the 1870s, English physician and inventor Joseph Mortimer Granville developed the first (enormous) battery-powered vibrator. Granville doubted its utility to treat nervous disorders, indicating that orgasm's utility was not an undisputed consensus, but nonetheless, the vibrator was used for the first time publicly on a hysterical woman at the Pitié-Salpêtrière hospital in Paris. No longer would doctors labor for up to an hour to

relieve patients; instead, they could conclude a session in as little as 5 to 10 minutes.

By the turn of the century, several models of vibrator had flooded the market. In response, physicians unsuccessfully experimented with the use of vibrators elsewhere on the body to treat a number of conditions, including on the head for baldness, on the joints for arthritis, and on the stomach for obesity. Even men's impotence was treated with vibration.

Medical professionals soon abandoned vibrator use beyond its verified capacity to ameliorate female nervous disorders. Still-productive manufacturers recognized the commercial potential of vibrators as consumer products and quickly began marketing them to laypeople. Advertisements promised that vibration could strengthen muscles as efficiently as exercise and miraculously cure internal maladies such as indigestion when applied to the body. Mindful of appearances, doctors purchased only the most sophisticated models.

Still, vibration had already departed the exclusive province of medicine and would never return. The electrification of most urban American homes by 1900 invited new electronic appliances such as the sewing machine, fan, teakettle, toaster, and vibrator. Convenience and price, roughly the cost of four to five doctor visits, pushed many women to buy their own vibrators. Mail-order versions had largely replaced medical contraptions by 1920. Vibrator advertisements and purchase abruptly discontinued during the next decade, probably due to the explosion of vibrator use in contemporary pornography, which shattered the respectable veneer crafted by advertisers in previous decades.

Vibrators were relatively rare commodities from 1930 into the 1960s, only occasionally appearing for sale as "massagers" in downmarket magazines. The sexual revolution of the 1960s, brought on by the birth control pill, youth counterculture, a growing feminist movement, and advances in sexology, recovered the vibrator from obscurity. Marketing for the newly cordless device actually highlighted its sexual function, though some like the Hitachi Magic Wand, the most popular vibrator in America after its introduction in 1968, simply advertise themselves as "personal massagers."

Vibrator manufacturers continue to innovate as technology improves. Newer models boast adjustable speeds and novel attachments, lifelike appearances (when shaped like a penis or other object), and remote-operated ones in sizes small enough to be discreetly inserted and capriciously activated. American culture has embraced the return of the vibrator. A 2009 study found that about 53 percent of women aged 18 to 60 have used vibrators, and recent users indicated more positive sexual function.

Kyle Bridge

See also *Vol. 2, Sec. 3: Tampon; Vol. 3, Sec. 1: Birth Control Pill*

Further Reading

Herbenick, D., et al. 2009. "Prevalence and Characteristics of Vibrator Use by Women in the United States: Results from a Nationally Representative Study." *The Journal of Sexual Medicine* 6, no. 7 (July): 1857–66.

Maines, Rachel P. 1999. *The Technology of Orgasm: "Hysteria," the Vibrator, and Women's Sexual Satisfaction*. Baltimore: Johns Hopkins University Press.

Water Heater

Norwegian American Edwin Ruud invented the first modern water heater in 1889. Ruud's invention was a gas-powered, storage tank-type heater.

Edwin Ruud was born in Askin, Norway, on June 9, 1854. He immigrated to Pittsburgh, Pennsylvania, in 1880. Ruud worked with George Westinghouse to develop products related to gas power. He left Westinghouse to focus on water heater technology and established Ruud Manufacturing in 1897.

Prior to Ruud's invention, water heating was uncommon in homes and for only the very rich. No one knows who created the first water heater; they did exist before Ruud. But they were expensive, unreliable, and difficult to operate. Ruud improved the design and created an affordable and safe heater that became popular in the United States. The first patent for this product was issued in 1889.

Previous water heaters would store water and heat it, meaning that there was a limited amount of hot water one could use before having to wait for the tank to refill. Diagrams of Ruud's water heater show that it utilized a coil system, which water would pass through above an open fire. These systems relied on natural gas for power. In addition, Ruud's diagrams suggested road maps for plumbing pipes that would carry hot water throughout a house.

Since the 20th century, tankless water heaters have been gaining popularity, because they are both environmentally friendly and less expensive to operate than traditional water heaters. Solar-powered water heating also exists, with the heaters working in conjunction with solar panels.

Peg A. Lamphier

See also *Vol. 1, Sec. 1: Franklin Stove; Vol. 1, Sec. 3: Electric Stove; Vol. 2, Sec. 2: Hoosier Cabinet*

Further Reading

Ogle, Maureen. 2000. *All the Modern Conveniences: American Household Plumbing, 1840–1890*. Baltimore: John Hopkins University Press.

Weather Forecasting. See Abbe, Cleveland

Westinghouse Air Brake

The railroad industry, more than any other, defined the 19th-century explosion of technology and invention. It was the industry that birthed Thomas Edison, Andrew Carnegie, Henry Bessemer, and George Westinghouse (1846–1914). The railroad industry maintained almost 100 years of exponential growth, driving a world industrial boom spurred partly by Westinghouse's railroad technology. In 1850, there were only 9,000 miles of track in America; by the end of the Civil War in 1865, there were around 35,000 miles. By 1874, there were 77,740 miles, and by 1900, there were 198,964 miles. At the time of Westinghouse's death in 1914, there were over 250,000 miles of track.

By 1890, the American railroad industry's gross income exceeded \$1 billion, with the capital invested totaling over \$10 billion. The weight of goods moved increased enormously—from 90 million tons in 1860 to 235 million in 1880 and 425 million in 1900. These are staggering numbers even by today's standards. The 19th century's richest men, such as Cornelius Vanderbilt, John D. Rockefeller, Carnegie, and J. P. Morgan, made their money in the railroads' growth. Innovation and involvement in the railroad industry was a way to riches from 1870 to 1920.

Yet, as the railroads grew, accidents grabbed the headlines with grim news of death and injury. In 1853, President Franklin Pierce's young son was killed in a passenger train derailment, and Charles Dickens was in a major brake-failure wreck in 1865. An 1856 crash in central Pennsylvania killed over 50 people, mostly children on their way to a Sunday picnic. The public was becoming fearful of rail travel, and newspaper editorials called for industry action on safety. If the industry didn't address the problem, the government would step in to regulate it. Besides passenger safety, the lack of an adequate braking system also affected business by limiting the length of trains to 10 freight cars.

The hand brake system in place required coordination and muscle power. The locomotive engineer would start throttling down the engine as he signaled the brakemen with the whistle (known as the "down brakes whistle"). A brakeman was assigned between every two cars on the train. The brakeman would begin the process of applying friction brakes on each car by turning a hand wheel known as the horizontal wheel, located on a vertical post at the end of each car; the hand wheel multiplied the force of the brakeman's muscles. The needed strength of the brakemen was the source of the term "Armstrong system." The hand wheel pushed brake shoes on each car against the wheels. After the brakes were applied to one car, the brakeman jumped to the other car to apply its brakes. Poor coordination between the brakemen could cause "locking" and serious danger to both the passengers and the brakemen. The brakemen had to race from car to car, often on roofs slippery with ice, snow, and rain. It was estimated that 1,000 brakemen were killed each year and another 5,000 injured.

George Westinghouse already had a railroad equipment business and was looking for new products. He had been a vigorous reader of the technical and engineering journals from his earliest days at his father's plant. By 1868, compressed-air tooling was making news as new tunnels were being built all over the world. Westinghouse immediately saw the application of compressed air to railroad braking as a means to transfer energy to a braking system. A Pittsburgh train was equipped with the Westinghouse system in September 1868. (This date has been confused with April 13, 1896, the actual date that the patent was issued.) The train left a tunnel at 30 miles per hour only to see a merchant and his cart stalled on the street crossing. The train hit the brakes, stopping in time—a spectacular demonstration for Westinghouse's innovation.

If done well at 30 miles per hour, hand braking could stop a train within 1,600 feet. The Westinghouse "straight air brake" could do it within 500 feet. Word of the trial traveled quickly in local railroad circles, but the railroads were cautious. First, to many railroad executives, brakes were a safety issue, not a profit issue. In fact, Westinghouse's success struck fear in many because of the potential cost of converting all existing trains. One estimate was that \$40 million would have been needed in 1875 to convert the industry (equivalent to as much as \$1 billion in today's money). In July 1869, Westinghouse Air Brake was formed with a board of directors from the enthusiastic railroad executives. The board consisted of 22-year-old Westinghouse, Robert Pitcairn, W. Card, Andrew Cassatt, Edward Williams, G. Whitcomb, and Ralph Baggaley. The capitalization was \$500,000. Westinghouse sold the railroads on the air brake, showing that it would not only be a savings compared to the federal regulation that was moving through Congress, but that its use could more than triple the tonnage carried on freight trains. By 1874, Westinghouse brakes were on 20 percent of the nation's trains.

Westinghouse needed to standardize his parts and assembly to make his endeavor a commercial success. His manufacturing system was as revolutionary as his air brake. With the booming sales of the automatic brake, Westinghouse was in need of good mechanics and machinists. Hourly wages for such skilled employees were around \$2.50 per hour, but Westinghouse

devised a piece rate system in which employees could earn as much as \$4 an hour. Westinghouse's preceded the famous Frederick Taylor piece-incentive system by 20 years. Westinghouse's manufacturing system was the first to offer employee pensions and health care, and he developed a system of internal education and paid employees to go on to attend college. He was one of the earliest manufacturers to hire women in the factory.

Westinghouse featured his braking system at the 1876 Philadelphia World's Fair. By 1879, Westinghouse had installed his system on 3,600 locomotives and 13,000 cars. In 1893, Congress required the air brake and automatic coupler on all trains and passed the Railroad Safety Appliance Act. The act was the result of the work Westinghouse and his friend William McKinley, chairman of the Ways and Means Committee (and future president). When Westinghouse started making air brakes in 1869, freight trains were 15 cars long, carried 300 tons, and averaged 30 miles per hour. At his death in 1914, they were 130 cars long, carried 7,000 tons, and averaged 60 miles per hour. The brake gave huge profits to the railroads. Westinghouse brakes were on over 3 million cars and 80,000 locomotives in this country alone by 1916, and Westinghouse had covered as much as 70 percent of the world market.

Quentin R. Skrabec

See also *Vol. 1, Sec. 3: Railroads*

Further Reading

- Derry, T. K., and Trevor Williams. 1960. *A Short History of Technology*. New York: Oxford University Press.
- Leupp, Francis. 1918. *George Westinghouse: His Life and Achievements*. Boston: Little, Brown.
- Skrabec, Quentin. 2007. *George Westinghouse: Gentle Genius*. New York: Algora.

Windmill. See Metal Windmill

World's Fairs

World's fairs, or expos, are public exhibits that showcase manufacturing, arts and crafts, science, technology, and other aspects of a collection of countries.

Modern world's fairs can trace their heritage back to the 1844 French Industrial Exposition and the 1851 Crystal Palace Exhibition in London, formally known as the Great Exhibition of the Works of Industry of All Nations.

Early fairs were held wherever and whenever a country decided to create an exhibit, but in November 1928, 31 nations came together to form the Bureau International des Expositions (Bureau of International Expositions, or BIE). The organization's role was a supervisory one, and by officially sanctioning world's fairs, it was thought that the BIE would help countries maintain fiscal control on their exhibits by limiting the number of events in progress at any given time. World's fairs that have been registered with the BIE may be held once every five years, and registered expos (smaller events) may be held between world's fairs.

Throughout the 19th century, world's fairs mainly showcased advancements in industry and inventions, but by the mid-20th century, they were pursuing cultural exchange and understanding in addition to technology and science.

The earliest unofficial world's fair held in the United States was the 1853 New York City Exhibition of the Industry of All Nations, which opened on July 14, 1853. The fair was dominated by the New York Crystal Palace, an opulent steel and glass structure modeled on the British Crystal Palace of 1851. Reservoir Square, on the outskirts of the city, was chosen for the location, and an architectural competition was held, which was won by George Carstensen (1812–1857) and Charles Gildemeister (1820–1869).

Adjacent to the Crystal Palace was the Latting Observatory, a 315-foot wooden tower that allowed visitors a panoramic view of New York and New Jersey. At the fair, Elisha Otis demonstrated his new elevator, which was equipped with a safety brake.

The 1876 Philadelphia Centennial Exposition was the first official world's fair to be held in the United States. It was officially opened on May 10, 1876, by President Ulysses S. Grant (1822–1885) and ran until November 10. Thirty-five countries participated in the fair, which drew an estimated 10 million visitors to its more than 30,000 exhibits, including a 650-ton, 70-foot-tall Corliss steam engine and a telephone.

American animals were put on display, along with rocks and minerals. Fifty-three Native American tribes camped on the fairgrounds, having been brought to the fair to show their way of life to attendees.

The 1893 Chicago World's Columbian Exposition was homage to the 400th anniversary of Christopher Columbus's expedition to the New World. The fairgrounds were designed by landscape architect Frederick Law Olmsted (1822–1903), who settled on a classical theme for the exposition's buildings. Dubbed "the White City," the fair's architecture helped spur the adoption of the City Beautiful Movement philosophy of urban planning.

The fair covered more than 600 acres of land and opened to visitors on May 1, 1893, running through the end of October. More than 27 million visitors flocked to the fair, taking rides on the Ferris wheel designed and built by engineer George Washington Gale Ferris Jr. (1859–1896). The wheel was 264 feet tall and could carry more than 2,000 passengers at a time.

Many technical innovations were displayed at the fair, including the first fluorescent lightbulbs, and at night, the buildings were lit by electric lights powered by alternating current. The Yerkes telescope was on display in the Manufactures and Liberal Arts Building until the building caught fire in November.

The Columbian Exposition was the first world's fair to include national pavilions, and nearly 50 countries attended, as well as many states and territories. The Liberty Bell was sent from Philadelphia and was put on display in the Pennsylvania Building.

The next American world's fair was the 1901 Pan-American Exposition held in Buffalo, New York. It was known as the "Rainbow City" for the liberal use of color in its architecture, such as the 375-foot green Electric Tower lit at night by more than 40,000 lightbulbs with power drawn from Niagara Falls.

The Pan-American hosted a variety of exhibits that included the Model Dairy, agricultural machinery, and an infant incubator that demonstrated its use in the treatment of premature babies.

In 1904, St. Louis, Missouri, hosted the Louisiana Purchase Exposition in celebration of the Louisiana Purchase centennial. More than 200 buildings housed a variety of technological, scientific, and anthropological

exhibits, which included indigenous peoples “on display” and a reconstruction of a traditional Igorot Philippine village. The scientific exhibits included a demonstration of wireless telegraphy and meteorological balloons.

The 1915 Panama-Pacific International Exposition was held in San Francisco’s Marina District to celebrate the completion of the Panama Canal. The fair was officially opened by President Woodrow Wilson (1856–1924) on February 20 and ran through early December.

Twenty-four countries participated in the 635-acre fair, and its buildings included the Tower of Jewels, which contained thousands of fragments of colored glass, and the Palace of Fine Arts, which is the only remaining structure from the fair. The Hawaiian presence popularized the ukulele.

The 1933 Chicago World’s Fair opened on May 23, commemorating the city’s 100 years of incorporation with the theme “A Century of Progress.” Buildings included the Havoline thermometer, a 218-foot structure that used neon lights to display an accurate temperature. The Travel and Transportation building housed a railroad exhibit, and the Homes of Tomorrow Exhibition introduced consumers to new building materials and prefabricated homes.

The 1939 New York World’s Fair opened on April 30, 1939, with the theme “Building the World of Tomorrow.” It covered 1,216 acres of a former dump in Queens and boasted some of the most memorable architecture of any fair, including the two buildings that became its symbols: the Trylon and Perisphere.

The fair was organized into seven zones, which included the Government Zone and its Hall of Nations and country pavilions, the Communications and Business Zone, the Transportation Zone, Amusement Zone, and Food Zone. The Futurama ride, sponsored by General Motors, gave attendees a taste of what life in the future would look like.

Among the technology exhibited at the fair were air-conditioning and television sets. President Franklin D. Roosevelt became the first American president to appear on television when RCA transmitted his opening speech.

The 1939 Golden Gate International Exposition was held on San Francisco’s man-made Treasure

Island, with the theme “Pageant of the Pacific.” The fair’s name acknowledged the newly built Golden Gate and San Francisco–Oakland bridges and was intended to honor their construction, as well as promoting unity in the Pacific.

The fair’s architectural style combined elements of eastern and western design, which later became known as “Pacifica,” named for the statue of the goddess of the Pacific. The fair was bisected by two main thoroughfares that met at the Court of Honor, dominated by the 400-foot Tower of the Sun.

The 1962 Seattle Century 21 Exposition opened on April 21, 1962, on 74 acres of land. The fair’s iconic 605-foot Space Needle lifted thousands of attendees to its 520-foot tall observation deck, while the monorail carried them around the fairgrounds, which included buildings that housed exhibits on science, commerce, art, and entertainment.

Back on the east coast, the 1964 New York World’s Fair opened in April 1964 on the original site of the 1939 fair and ran through October 1965, drawing an estimated 52 million visitors. It included industrial, international, federal and state, and transportation exhibits, with a heavy focus on a utopian future where machines and modern materials would make life easier.

The fair’s modern architecture included the 120-foot stainless steel Unisphere and the New York State Pavilion, both of which remain. Attractions featured Disney’s “Small World” exhibit, Dinoland, and the Futurama II ride, while technology on display included a demonstration of color television and computer-related technologies.

The 1968 San Antonio HemisFair featured a variety of national and corporate pavilions; there was the 1974 Spokane, Washington, Expo ’74, which eschewed technology in favor of environmentally themed exhibits; and the 1982 Knoxville International Energy Exposition.

The 1984 New Orleans Louisiana World Exposition was the last world’s fair to be hosted in the United States, which has not been a BIE member since 2001.

Karen S. Garvin

See also Electricity, War of the Currents; Electrification, Urban; Ferris Wheel; Yerkes Observatory; *Vol. 1*,

Sec. 2: Lewis and Clark Expedition; Vol. 1, Sec. 3: Elevator Safety Brake; Sewing Machine, Automated; Steam Locomotive; Telegraph; Vol. 2, Sec. 2: General Motors (GM); Panama Canal; Vol. 2, Sec. 3: Television

Further Reading

- Boisseau, T. J., and Abigail M. Markwyn, eds. 2010. *Gendering the Fair: Histories of Women and Gender at World's Fairs*. Urbana: University of Illinois Press.
- Larson, Erik. 2004. *The Devil in the White City: Murder, Magic, and Madness at the Fair That Changed America*. New York: Vintage Books.
- Rydell, Robert W., John E. Findling, and Kimberly D. Pelle. 2000. *Fair America: World's Fairs in the United States*. Washington, D.C.: Smithsonian Books.
- Samuel, Lawrence R. 2007. *The End of Innocence: The 1964–1965 New York World's Fair*. Syracuse, NY: Syracuse University Press.

Wright, Wilbur (1867–1912) and Orville (1871–1948)

Orville and Wilbur Wright, known by their joint moniker as “the Wright brothers,” were American inventors, engineers, and aviators known for designing, constructing, and piloting the first powered, controlled airplane. Prior to their first flight from Kitty Hawk, North Carolina, human flight had been achieved through aerostats, lighter-than-air vehicles that achieved lift via gas envelopes, such as hot air or hydrogen gas balloons. The closest semblance to powered flight at the time was the *LZ-1* created by Count Ferdinand von Zeppelin (1838–1917), the first rigid airship. The Wright brothers demonstrated that an aerodyne, an engine-driven, heavier-than-air craft controlled manually by a human pilot, was possible.

Orville Wright was born on August 19, 1871, near Millville, Indiana, and Wilbur on April 16, 1867, in Dayton, Ohio, to Milton Wright (1828–1917), a bishop and itinerant preacher with the United

Brethren of Christ, and Susan Catherine Koerner (1831–1899), a former student of literature at Hartsville College, Indiana, with notable mechanical aptitude. They were the middle two of five siblings, which also included Reuchlin (1861–1920), Lorin (1862–1939), and Katherine (1874–1929). Their father’s job required him to travel, and on an 1878 trip he brought back with him a toy helicopter based on a design by French aeronautical pioneer Alphonse Pénaud. This has been cited as the catalyst for the brothers’ interest in aviation.

In 1885 and 1886, Wilbur’s plans to attend Yale University after high school were disrupted by an ice hockey accident: he was hit in the face by a fellow player’s stick. While his injuries healed, Wilbur slipped into depression, cancelled his plans, and withdrew to the Wright family home in Dayton, Ohio, where he spent most of his time caring for his ailing mother, who died from tuberculosis in 1889. Meanwhile, Orville dropped out of high school, more interested in such hobbies as printing, which began with access to his father’s office at the United Brethren Printing Establishment. He assumed printing as a serious hobby when the Wright family returned to Dayton to stay in 1884.

In the late 1800s, Dayton experienced unprecedented growth and economic expansion as a center of manufacturing and industry. This made it ideal for technological innovation, setting the stage for the brothers’ initial business venture. In 1889, the brothers began their first collaboration in the small printing firm Wright & Wright, with Wilbur acting as editor and Orville as publisher. They managed a number of publications, including *The Midget* (a school newspaper), Church pamphlets, bicycle catalogues, *The Dayton Tattler*, and their own newspaper, *The West Side News* (later *The Evening Item*). At this time, they began using their moniker “the Wright brothers,” by which they would be best known for the rest of their lives. They sold the business in 1899 after their mother’s death and the departure of their only regular employee, Ed Small.

They then opened the Wright Cycle Company in 1893 to capitalize on the bicycle craze sweeping the United States after two-wheeled safety bicycles were

imported from Britain. The brothers gained a reputation for their skill in manufacturing and repairing bicycles, opening their own line to meet competition in 1895. The next year, James Howard Means, an editor for *The Aeronautical Annual*, published an article describing the relationship between the speculative craft of human flight and the existing technology of bicycle mechanics. Working with this logic, the brothers applied their skill in bicycle engineering and the resources of their shop to their reemerged ambition in aeronautical pioneering.

In the 1800s, there was a widespread community of scientists and engineers investigating possible methods of controlled flight, predominantly experimenting with manned gliders. Among them were Englishmen Sir George Cayley (1773–1857), the first to systematize aeronautical research according to the scientific method; Samuel Vince, who devised the equations for lift and drag; and German Otto Lilienthal (1848–1896), who compiled the largest volume of aerodynamic data of the time. Lilienthal's death in 1896 in a gliding accident had been cited by the brothers as the catalyst to their project to build a functioning flying machine. In 1899, the Smithsonian Institution granted Wilbur's request for all of their available aeronautical data, and that same year, the brothers began testing the first *Wright Kite* at Kitty Hawk, North Carolina—chosen for its strong winds. Their breakthrough occurred in synthesizing an earlier biplane model by Octave Chanute and Augustus Herring with the concept of “wing-warping”: by twisting the wings on either side to meet the oncoming airflow at two different angles, they could generate uneven lift on either side to bank and turn the kite at will, allowing the pilot to maintain balance. Unfortunately, a series of test glides in 1901 failed to surpass a distance of 300 feet and strongly discouraged the brothers.

The brothers conducted experiments to select wing shapes in a homemade wind tunnel, where they also collected aerodynamic data that allowed them to check for faulty coefficients in Lilienthal's data as well as correct Smeaton's coefficient in the lift and drag equations. With this new data, they were able to construct a second glider in 1902, and then the famed *Wright Flyer* in 1903. The final *Flyer* had a wing area

of 500 square feet, a spruce framework with ash ribs, covered in unbleached muslin woven at a 45-degree angle to enhance wing-warping ability, and a three-axis control system of two warping wings and a rudder. An engine was custom made with parts from a Dayton foundry, with two propellers and a chain-and-sprocket transmission system. On December 17, 1903, the Wright brothers successfully conducted three rail-launched test flights of their eponymous *Flyer*, the third of which was the longest at 59 seconds and traveling 852 feet. The brothers had successfully conducted the world's first controlled flight of a power-driven aerodyne.

With skepticism of their accomplishment everywhere, Wilbur traveled to Europe, soon joined by Orville and Katherine, to demonstrate their airplane. They held audiences with royalty, including King Edward VII of England, King Alfonso XIII of Spain, and Crown Prince Friedrich Wilhelm of Germany. Upon returning to the states in 1909, they became businessmen, filling contracts for airplanes in the United States and Europe, performing flight trials for the U.S. military, and beginning the Wright Company with their first commercial airplane in 1910.

In 1912, Wilbur Wright succumbed to typhoid fever and died at the Wright family home in Dayton at age 45. Orville sold his interest in the Wright Company in 1915 and the bicycle shop in 1916, and spent his remaining years promoting aviation and consulting with government boards and commercial airlines. He died on January 27, 1948, of a heart attack at age 76.

Andres Elvira

See also Velocipede; Vol. 1, Sec. 2: Submarine; Vol. 2, Sec. 2: Airplane; Vol. 2, Sec. 3: B-17 Flying Fortress; Curtiss-Wright Aeronautical Engineering Cadettes

Further Reading

- Grant, R. G. 2007. *Flight: The Complete History*. New York: DK.
- McCullough, David G. 2015. *The Wright Brothers*. New York: Simon & Schuster.
- Wragg, David. 1974. *Flight Before Flying*. Oxford: Osprey.

Primary Document: Entry from Orville Wright's Diary of December 17, 1903

Reproduced here is the description of the flight of the Wright Flyer on December 17, 1903, that Orville Wright committed to his diary later that day.

Orville Wright's diary, December 17, 1903

When we got up a wind of between 20 and 25 miles was blowing from the north. We got the machine out early and put out the signal for the men at the station. Before we were quite ready, John T. Daniels, W.S. Dough, A.D. Etheridge, W.C. Brinkley of Manteo, and Johnny Moore of Nags Head arrived. After running the engine and propellers a few minutes to get them in working order, I got on the machine at 10:35 for the first trial. The wind was blowing a little over . . . 27 miles. . . . On slipping the rope the machine started off increasing in speed to probably 7 or 8 miles. . . . Mr. Daniels took a picture just as it left the tracks. I found the control of the front rudder quite difficult. . . . As a result the machine would rise suddenly to about 10 ft. and then as suddenly, on turning the rudder, dart for the ground. A sudden dart when out about 100 feet from the end of the tracks ended the flight. Time about 12 seconds (not known exactly as watch was not promptly stopped.) . . .

After repairs, at 20 min. after 11 o'clock Will made the second trial. The course was about like mine, up and down but a little longer over the ground though about the same in time. Dist. not measured but about 175 ft. . . .

At about 20 minutes till 12 o'clock I made the third trial. When out about the same distance as Will's, I met with a strong gust from the left which raised the left wing and sidled the machine off to the right in a lively manner. I immediately turned the rudder to bring the machine down and then worked the [wing-warping] control. Much to our surprise, on reaching the ground the left wing struck first,

showing the lateral control of this machine much more effective than on any of our former ones. At the time of its sidling it had raised to a height of probably 12 to 14 feet.

At just 12 o'clock Will started on the fourth and last trip. The machine started off with its ups and downs as it had before, but by the time he had gone over three or four hundred feet he had he had it under much better control, and was traveling on a fairly even course. It proceeded in this manner till it reached a small hummock out about 800 feet from the starting ways, when it began its pitching again and suddenly darted into the ground. The front rudder frame was badly broken up, but the main frame suffered none at all. The distance over the ground was 852 feet in 59 seconds. . . .

After removing the front rudder, we carried the machine back to camp. We set the machine down a few feet west of the building, and while standing about discussing the last flight, a sudden gust of wind struck the machine and started to turn it over. All rushed to stop it. Will who was near one end ran to the front, but too late to do any good. Mr. Daniels and myself seized spars at the rear, but to no purpose. The machine gradually turned over on us. Mr. Daniels, having had no experience in handling a machine of this kind, hung on to it from the inside, and as a result was knocked down and turned over and over with it as it went. His escape was miraculous, as he was in with the engine and chains. The engine legs were all broken off, the chain guides badly bent, a number of uprights, and nearly all the rear ends of the ribs were broken. One spar only was broken.

After dinner we went to Kitty Hawk to send off telegram to M.W. [Milton Wright, their father].

Source: Wilbur Wright and Orville Wright papers, 1809–1979. Library of Congress.

Yerkes Observatory

Yerkes Observatory of the University of Chicago is located at Williams Bay on Lake Geneva, in southeast Wisconsin. The 40-inch diameter telescope was

completed in 1897 and today remains the largest refracting telescope in the world. It continues to be used for solar and stellar spectroscopy and for observation of double stars. Yerkes is considered to be the birthplace of modern astrophysics.

In September 1892, George Ellery Hale (1868–1938), then a new professor of astrophysics at the University of Chicago, learned that two 42-inch blank glass disks, which had been ordered by the University of Southern California from the Parisian glassmaking firm Mantois, were for sale. Hale realized that they could be used to construct a 40-inch telescope, and he requested the University of Chicago to buy the disks.

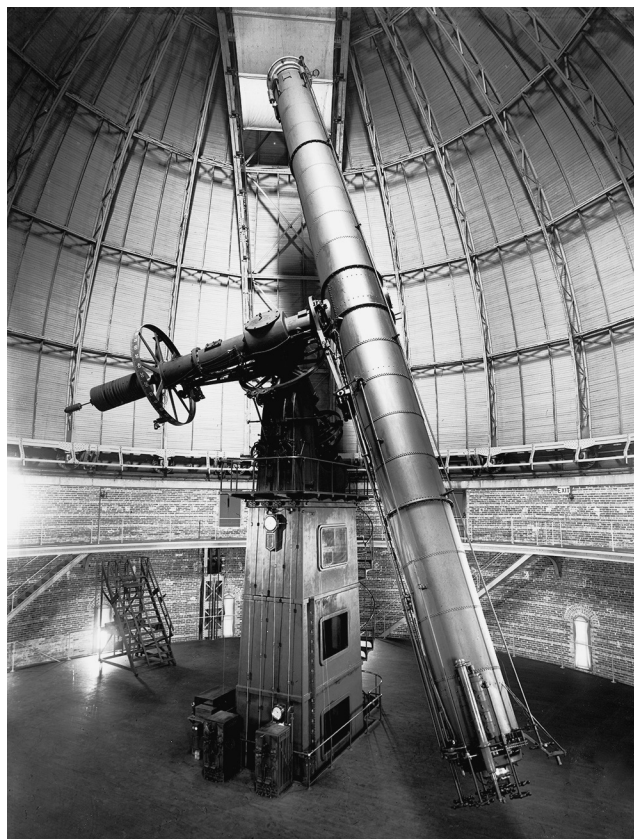
In October Hale and university president William Rainey Harper (1856–1906) approached streetcar magnate Charles Tyson Yerkes (1837–1905) to provide funding for the new observatory. They appealed to the businessman's sense of pride by telling him that James Lick (1796–1876) would be forever remembered for the telescope he funded. Yerkes, not about to be outdone, was persuaded to make a gift to the university.

As soon as the observatory plans were announced to the public, potential donors began to compete for the building site; a total of 27 parcels of land were on offer. Hale needed to winnow down the choices, and so he took into account factors such as the effects of nearby city lights and the heating effects that traffic and bodies of water might have on the telescope's performance.

In March 1893, a university committee recommended a 53-acre parcel of land along the edge of Lake Geneva, 70 miles northwest of Chicago. In December, it was officially chosen as the site, and Yerkes hired Chicago architect Henry Ives Cobb (1859–1931) to design the observatory building. Cobb's classical design included ornate carvings, some of which depict astronomical subjects. Construction began on the cross-shaped building in 1895 and was completed in 1897. The observatory grounds were designed by landscape architect John Charles Olmsted (1852–1920).

The Massachusetts optical company Alvan Clark and Sons was chosen to prepare the glass for the telescope. Cleveland instrument manufacturer Warner and Swasey was selected to build the telescope tube and its 90-foot diameter dome.

The massive telescope mount stood 43 feet high, and the tube measured 60 feet in length. The mounting tube, sans lenses, was completed in time to be put on



The refracting telescope at Yerkes Observatory is still the largest of its kind. The 40-inch tube was first exhibited at the 1893 Chicago World's fair before being installed at the observatory. (Mondadori Portfolio via Getty Images)

display in the Manufactures and Liberal Arts Building at the Chicago Columbian Exposition, which opened in May 1893. In November a fire threatened the telescope, but it was dismantled and safely removed from the exhibit building.

The observatory was formally dedicated on October 21, 1897, at the conclusion of a three-day conference that drew astronomers and astrophysicists from around the world. The observatory's equipment included the 40-inch refractor, a 10-inch photographic telescope, and a variety of specialized equipment that included solar and stellar spectroscopes.

Yerkes was one of the first facilities to do astrophysical research as well as observation, and it has been home to many famous astronomers and astrophysicists, including Edward Barnard, Gerard Kuiper, and Frank Ross.

Hale served as the observatory's first director, and in 1895, along with astronomer James Edward Keeler (1857–1900), established the peer-reviewed *Astro-physical Journal*. Hale was succeeded by Edwin Brant Frost (1866–1935), who chaired the department from 1905 through 1932 and developed a graduate program at Yerkes.

Today Yerkes houses the 40-inch refractor, along with 24-inch and 40-inch reflecting telescopes. The observatory offers guided tours and public programs that include the opportunity for an observing session with the 40-inch refracting telescope. The building also houses a volunteer-run museum dedicated to the astronomers of Yerkes.

Karen S. Garvin

See also World's Fairs; *Vol. 1, Sec. 1*: Astronomical Almanacs; Rittenhouse, David; Winthrop, John; *Vol. 1, Sec. 2*: Diffraction Grating; *Vol. 2, Sec. 2*:

Cannon, Annie Jump; *Vol. 3, Sec. 3*: Hubble Space Telescope

Further Reading

Bolotin, Norman, and Christine Laing. 2002. *The World's Columbian Exposition: The Chicago World's Fair of 1893*. Champaign, IL: University of Chicago Press.

Franch, John. 2006. *Robber Baron: The Life of Charles Tyson Yerkes*. Champaign: University of Illinois Press.

Hirshfeld, Alan. 2014. *Starlight Detectives: How Astronomers, Inventors, and Eccentrics Discovered the Modern Universe*. New York: Bellevue Literary Press.

Osterbrock, Donald E. 1997. *Yerkes Observatory, 1892–1950: The Birth, Near Death, and Resurrection of a Scientific Research Institution*. Chicago: University of Chicago Press.

2. The Progressive Era and the Roaring Twenties (1900–1929)

OVERVIEW

As the United States emerged from the 19th century and all but barreled into the 20th, the country bore little resemblance to the fledgling nation that had embarked a century and a quarter before on an audacious experiment in democratic government. Its triumph in the Spanish American War signaled its arrival on the world stage, and fueled by a string of innovations and advancements that had helped establish its place among the world's economic leaders, the United States was ready to assume its new place in the world. For many Americans, this new status was simply the latest example of the Manifest Destiny that had marked the nation's progress since the early part of the 19th century, but no less critical were a series of technology-powered and science-based changes that reshaped the American economic, cultural, and political landscapes. Indeed, as the new century began, the innovative spirit and talent that had produced those changes and advances continued apace. At the same time, however, a new generation of reformers began to look for ways to harness and redirect the nation's creative power and its talents for discovery and innovation so it could serve the broader national interest and make daily life better for all Americans. Those efforts, which would include previously unimagined governmental activity, would cause the first decade and a half of the 20th century to be known as the Progressive Era.

The early days of the Progressive Era saw the crowning achievement of the nation's growing industrial might when in 1903, the nation's first billion-dollar corporation was formed with the creation of U.S. Steel. The new corporation, an exemplar of corporate innovation, was based in Carnegie Steel, a company

whose vertically integrated operations had made it the dominant force in the steel industry, and which, when merged with others to form U.S. Steel, represented the culmination of efforts by financier J. P. Morgan to achieve the most efficient way to produce the steel so central to America's industrial economy. And indeed, the creation of U.S. Steel was a corporate triumph. However, as celebrated as it was, U.S. Steel embodied the concerns of reformers who believed that the nation's industrial colossus had been built on the backs of the nation's working men, women, and children. Protecting these human cogs in the industrial machine would, over the next decade, become the focus of this era's reformers. In fact, when one thinks of science and technology as they relate to the Progressive Era, it is often in the context of the unprecedented level of governmentally administered regulatory efforts designed to tame technological advances past, present, and future. Indeed, those efforts are in many ways at the heart of the Progressive Era. But in reality, the truth lies somewhere in between. For while regulation was often necessary, regulation could not stop the ongoing advancement and innovation that had come to characterize the modern America that was emerging in the first decades of the 20th century.

Planes, Trains, and Automobiles

Nothing reflects the scientific and technological advances of the Progressive Era more fully than the automobile. On a seemingly annual basis, new inventions and innovations, large and small, were unveiled, and by the end of the Progressive Era and World War I, the horseless carriage had experienced a radical transformation in areas ranging from its production to

its appearance to what was “under the hood.” Beginning with the invention of the assembly line, a development that Henry Ford would adapt and refine in a way that ultimately revolutionized industrial production well beyond that of the automobile, the car was transformed, and it in turn transformed the nation. As Ford’s assembly line made the Model T something that was not simply a toy of the very wealthy, the increased use of the car transformed not only the way the nation traveled but also countless other aspects of American society. Indeed, many of those changes could be seen in the developments, large and small, that emerged during the Progressive Era.

Examples of these related and ultimately important developments included the 1912 invention of the traffic light, which was complemented by the development of traffic cones that same year. These had, in fact, been preceded by the development of windshield wipers. All these advances, not to mention the annual and substantial increases in road travel, made safety-based developments particularly important with the road markings, most often presented as a dividing line down the center of a road, that debuted in 1912 and the invention of the tow truck in 1913, doing much to make the driving experience safer and thus one that a driver could undertake with significantly greater confidence. Indeed, this was seen in other ways as well. Spurred by the need for better tires for an ever-increasing amount of travel, automakers drew upon Charles Goodyear’s previous work with vulcanized rubber and were able to incorporate it into the tires upon which the burgeoning auto industry rode. Too, the cars themselves got an upgrade with the development of both the automatic transmission in 1904 and, soon afterward, the automatic starter that replaced the old cranking method that was so richly satirized in the movies that were becoming an increasingly popular form of entertainment at the time.

Of course, the developments in the automotive world and especially Henry Ford’s assembly line were just one, albeit the most high-profile, area where the efficiency craze was sweeping the world of commerce. Indeed, much of the desire to invent, improve, and refine in order to achieve increased efficiency was reflective of the influence of Frederick Winslow Taylor and his theory of scientific management. Seeking

to maximize each laborer’s efforts, Taylor, utilizing his background in mechanical engineering, analyzed the labor process in a never-ending search for the most efficient way to do a job. He undertook “time and motion” studies that looked at the way in which a worker performed his or her task. He also analyzed the equipment used, an effort that at one point resulted in the designing of a shovel that allowed a worker to shovel for a longer continuous period. At the same time, Taylor believed that workers were motivated by money, and he championed the idea of “a fair day’s pay for a fair day’s work,” a concept that would reward the best workers. He also believed that certain people, in fact, worked more efficiently and effectively than others, and as a result, he urged employers to pay great attention to getting the right person for each job. From all of this research, Taylor developed four fundamental principles of scientific management, a set of beliefs that came to be known in some circles as “Taylorism.” They included a change from an accepted or habit-based approach to a job to a scientific review of the work to determine the best way to perform it; the assigning of workers to jobs based on their abilities and motivations, and to then train them so they could address the job in the most efficient way; the oversight and review workers’ performances and the provision of instruction and supervision to ensure that the most efficient ways were being utilized; and the division of labor between managers and workers so that managers could focus on training and planning to enable workers to do their jobs as efficiently as possible. For all its influence, Taylorism was not without its critics. While scientific management reflected the thoughtful, science-based problem-solving approach central to much of progressivism, critics of Taylor’s work also charged that the increasing efficiency often clashed with humanity. Such a concern was no less a part of a Progressive Era that saw the passage, at both the state and federal levels, of some of the first protective legislation aimed in particular at preventing the exploitation of workers, especially women and children.

While the Progressive Era saw a range of developments related to the automobile that would lead to a revolution in land travel, the Wright brothers’ inaugural airplane flight in December of 1903 began a process that led to a similar revolution in air travel as well as

modern warfare, with the latter change becoming very evident in World War I. Indeed, while the Wright brothers undertook continuing efforts to move their invention forward, they were joined by countless others anxious to be a part of an invention that would eventually transform American and world culture. In the end, the Progressive Era saw a raft of inventions, innovations, and new developments that would swiftly revolutionize the developing field of aviation. Among these later innovations was the first takeoff from a ship, a feat first accomplished in November 1910 by Eugene Ely, who flew from the deck of a ship anchored in Hampton Roads, Virginia, to a spot onshore. Just a few months later, in January 1911, he reversed course. Relying upon hooks that he had attached to the plane's landing gear in a significantly less sophisticated forerunner of a modern arresting gear, Ely took off from shore and landed on a ship anchored off the California coast. The ensuing years saw a wave of inventors and innovators refining and improving the basic aircraft, with their efforts leading to greater maneuverability, higher speeds, the ability to fly at higher altitudes, and greater structural strengths. These developments and more would all be tested with the advent of World War I.

Radio, Moving Pictures, and Mass Culture

Similarly, communication in the broadest sense was also undergoing some major changes as inventions, including Marconi's radio, coupled with advances in both the telephone and motion pictures, had a major impact on the nation's economic and cultural development. Radio itself, the beneficiary of continual improvements and tweaks ranging from the addition of tuners to the creation of condenser microphones that enhanced the broadcasting process, provided a whole new venue for the arts. Indeed, the first American broadcast in 1906 of voice and music ushered in a whole new chapter in popular entertainment. So quickly did things change that the U.S. government passed the first laws regulating radio in 1912. Meanwhile, at this time, entrepreneur David Sarnoff, who had begun working for a local Marconi company while still in his teens, began to first envision radio as "a household utility," and his early efforts to establish what would become the first radio network marked the

beginnings of a career that would vault him to the forefront of the American radio and television industries.

This period also witnessed major advances in film and photography, including the production of the first animated cartoons, the first color motion picture, and the earliest effort to bring sound to motion pictures. But even without sound, movies became a cultural phenomenon. *The Great Train Robbery*, released in 1904, captured the nation's imagination and ignited a hunger for action films. By 1915 full-length feature films began to appear, which only increased the nation's appetite for the new form of entertainment. These milestones were powered by technology like the replacement of the hand-cranked movie camera with a motorized version. Some of this technology was also making its way into the home, as Kodak developed the Brownie camera that made taking pictures far simpler and cheaper than ever before. Shortly thereafter, Bell and Howell developed a film projection system that would eventually make home movies a veritable American memory bank, while the development of the picture postcard during this same period created ready-made memories for travelers and tourists alike. And photographic efforts were further enhanced by the development of optical rangefinders for cameras, while the development of rotogravure helped aid the quality of magazine photos. All these new visual entertainment options were increasingly accompanied by soundtracks and musical developments that ran seemingly parallel to the visual advancements. Beyond the radio that has been discussed, there was the development of the double-sided phonograph disc as well as the first jukebox, a machine that offered 24 song possibilities. Soon the fledgling radio stations began to air voice and music productions, and in 1907, DeForest Radio began to offer regular music programming.

Wealth v. the People

The scientific and technological inventions and innovations that had fueled the nation's industrial rise at the end of the 19th century laid the foundation for this next round of scientific and technological advances. But they also encouraged—indeed, all but forced—a new set of players, the local, state, and national governments, to undertake their own form of counterinnovations in response to

the nation's ever-changing, ever-growing, innovation-inspired economy. The governmental innovations that arose in response to the technological ones were themselves an important development of the period. A government that had once been at the beck and call of the industrial titans now found itself forced to confront those same powers. The political high water mark of the Progressive Era was arguably the 1912 presidential campaign, where Theodore Roosevelt's New Nationalism and Woodrow Wilson's New Freedom offered distinct visions of how the nation's growth and development could continue—but not at the expense of the people that the government was pledged to serve. Yet these federal proposals, in fact, represented a second wave coming on the heels of efforts by innovative and dynamic state and municipal political leaders who secured the first workers' compensation laws as well as other legislation addressing the regulation of public utilities, income taxes, referendum, recall, and many others. In fact, it was only after pressure from the states, as well from as the investigative journalists known as the muckrakers, that the federal government got into the regulatory game, passing legislation creating the Food and Drug Administration, the Federal Trade Commission, and the Department of Commerce all in an effort to limit the degree to which the nation's growing industrial might would be created on the backs of the working person and the immigrants flooding into the country.

Ultimately, these efforts represented a new approach to governing, one that sought to use the power of government in creative and innovative ways in an effort to address some of the many challenges that were arising in an ever-changing United States. At the same time, in the spirit of the era, the Progressives were using the same science- and technology-based approach in their own efforts to more fully identify the nation's problems and their roots—and then design appropriate solutions to the problems. Indeed, the fruits of scientific management could yield not only more efficient ways to do a job but also safer ones. The Progressives hoped that such study could yield the one best way to do a job and reduce the ability of employers to exploit their laborers. At the same time, certain of those problems required a human response, one that lay more in innovation than in science or technology. From the work of the settlement house pioneered by

Jane Addams to the trailblazing innovative legal approach embodied in the Brandeis Brief, Progressives brought a much-needed human dimension to a previously hidebound sector of a society that was forced to confront and respond to a rapidly changing American landscape.

Big Projects and Small Inventions

On a whole different level, the Panama Canal represented another impressive advancement of the kind that could be achieved when a presidential vision fueled governmental support of the nation's impressive technological know-how. The result was an engineering marvel that altered the shape of the world—or, at the very least, humanity's ability to traverse it. Indeed, the American canal construction effort, spanning the decade from 1903 to 1914, was an engineering triumph, one that opened new economic and transportation avenues. Approximately 50 miles long and featuring three sets of locks that addressed the different elevations on the ends of the structure, construction was a herculean effort. The project was a daunting endeavor, but its completion served to transform east-west trade both within the United States and around the world.

While discussions of scientific and technological advances, inventions, and discoveries tend to focus on the developments that have had the widest impact, no less important are the seemingly smaller things, for those developments, when multiplied by the sometimes millions of people who are affected, can certainly have a huge impact on larger society. In this vein, the Progressive Era was witness to a wide range of inventions and developments that made the daily lives of many Americans considerably easier, allowing for more leisure activity and in turn changing the very face of the nation's cultural landscape. From the development of the tea bag to curtain rods to Formica, life in the American home was transformed. Too, the invention and the introduction into American homes of the radio made it possible to be entertained without leaving the comfort of one's home.

Medical discoveries, inventions, and advances were also a part of the scientific and technological developments of the era. From the development of

hearing aids to the discovery of the importance of vitamins to human health, not to mention the first blood transfusions and the invention of the electrocardiogram, new advances in knowledge and understanding helped fuel the beginnings of a transformation that saw medicine become less a wholly reactive process but instead a profession that recognized that it could, in fact, play a valuable preventive role on the road to good health.

Life for the American homeowner also underwent massive change. Not all the efficiency-based developments were done under the eye of Frederick Taylor's stopwatch. Rather, there were many efficient, new products and innovations that simply made daily life easier, often allowing individuals and families to participate in some of the other developments of the time. As noted, advances in motion pictures added a whole new dimension to popular entertainment, itself a beneficiary of the many inventions and advancements that gave the middle class large amounts of previously unimagined leisure time. Developments like the vacuum cleaner did much to enhance domestic life. Similarly, the development of the disposable safety razor was a boon to many men, while little things like the creation of the window envelope and the flashlight made life just a little bit better. And, of course, for the few who could afford it, the invention of air-conditioning in 1902 represented a godsend in the midst of summer heat. On a more fundamental level, the 1906 invention of the flushometer, a water pressure system that lowered time between toilet flushes, represented a major advance, as well as the invention of the electric dishwasher. Equally simple but no less valuable for the Progressive Era family was the development of paper towels and paper cups.

Children's lives were also changing during this period, for beyond the protective legislation that was designed to allow children to experience, at least to some degree, their childhoods, new inventions and developments brought new excitement and enrichment to their lives. Foremost among these was the creation of the Hershey bars that satisfied their sweet tooth. Beyond that, the new marvels that brightened their lives ranged from the Lionel trains that allowed them to dream of life on the rails to the soft, cuddly comfort that could be found in teddy bears. Indeed,

American children were able to find a host of new ways to enjoy some of the new-found free time that the Progressive Era began to see. Meanwhile, the introduction of the comic book offered another way to engage young imaginations. Watercoolers, not to mention popsicles and ice cream cones, were also products of this era and helped make summertime heat far more tolerable—although, as noted, the introduction of air-conditioning allowed some people to truly escape scorching summer heat.

As with so many things, the scientific and technological advances of the period represented something of a double-edged sword. Indeed, for every indisputably positive advance, whether a large one like the electric dishwasher or a smaller, simpler item like a curtain rod, coat hanger, or thumbtack, there was the more nefarious invention of an item like the gun silencer. That, of course, is the reality of change, for while American children delighted in the introduction of Lincoln Logs, Erector Sets, and Tinkertoys, not to mention Life Savers candy, the society at large could not have imagined the subsequent impact that the 1916 patent granted to Maryland civil engineer Arthur Hale for his cloverleaf interchange would have on the still fledgling auto industry and ultimately upon car travel across the United States. Meanwhile, in offices across the country, employees reveled in new, time- and cost-saving developments ranging from stenotype machines to paper shredders, from water coolers to coffee filters, to the first electric typewriters. For the homemaker, the arrival of the supermarket made life much easier, offering a full array of items all in one place, a convenience that, befitting the times, made even shopping for basic foodstuffs a more efficient process. At the same time, on the domestic side, countless numbers of families were not only able to enjoy new amounts of leisure time, but they also had their lives made easier and more comfortable by the introduction of the mixer, electric blankets—the early version had the heat coming from underneath as one lay in bed—and the shopping bag.

The Technological Challenges of Urbanization

Many of the developments and advancements of the period represented responses to the nation's changing

demographics. By 1920, for the first time in the nation's history, the majority of Americans was living in urban areas. In addition, it was during this period that, for the first time, the majority of the country's workers was in factories and not on farms. Consequently, developments that fueled this now industrial and urban-based economy had a special importance, as did some of the domestic advances that impacted the lives of the families no longer operating on a farming-focused schedule. Indeed, these shifts led to a number of important technology-based changes, including streetlights and public utilities that represented an innovative governmental foray into a previously private sector-dominated arena. In fact, expansive new urban infrastructure developed alongside transportation systems featuring trolleys and streetcars as well as the elevated railways that had begun to arrive in the late 1890s. Ultimately, there would be subways in all major cities by 1920. These developments transformed the nation's cities, allowing people to live outside the cities and commute in—offering a preview, albeit on a significantly lesser level, of the development of the suburb. Of course, improved transportation was only one area in which the cities had to adapt to accommodate their increasing populations. Developing technology allowed the cities to develop the sewer-based sanitation systems that their increased populations required, and sanitation departments, as well as professional police and fire departments, emerged in the nation's largest cities. Too, limited space, coupled with increased need, led to changes in the nation's approach to urban housing. Illustrating architect Louis Sullivan's declaration that "form follows function," stone buildings replaced wood structures, and tenements were replaced by dumbbell tenements, which were in turn replaced by apartment buildings—all of which would be dwarfed by the skyscrapers that had started to appear near the end of the 19th century but which, by the Progressive Era, had reached another level both in terms of size and their status as a testament to American engineering innovation. Whether they housed apartments or served as office buildings, the towering structures that dotted the urban landscapes, especially in the land-strapped cities stretching from Chicago to New York,

were towering monuments to America's self-declared global primacy. Despite its distinctive character, the increased urbanization of the United States was done with a bow to the country's rural roots. Indeed, growing in the shadows of the skylines in many cities was a well-developed system of public parks, with New York City's Central Park, designed by Frederick Law Olmsted, being the exemplar of what they could be. Finally, the modern cities also began to develop what might be called a commercial infrastructure for their urban residents with department stores, chain stores, and restaurants gaining a new role and popularity in city dwellers' lives.

While most of these developments set the tone for the coming decade, the Progressive Era came to an abrupt end with the United States' entry into the Great War in April 1917. Indeed, while the adoption of constitutional amendments related to both Prohibition and women's suffrage still lay ahead, as the nation went to war, the reform spirit was subsumed by the war effort, followed by the tumultuous peace. Divisions over the nation's direction in the postwar world, as well as fears of new threats from abroad, translated into the Red Scare and massive postwar labor unrest, all of which left the nation seeking stability and calm. That desire translated into the election as president of Senator Warren G. Harding. Indeed, buoyed by a resounding mandate in the 1920 contest, Harding prepared to lead the country in its "return to normalcy," one that, based on the first two decades of the 20th century, would mean a continuation of the advances in science and technology that were so much a part of the Progressive Era.

However, as the Republican administration settled in, it became clear that there would be a change in the role of government. Indeed, it was soon evident that the activist government that had characterized the Progressive Era had been replaced by a hands-off approach, one best seen in the assertion by Harding's successor, Calvin Coolidge, that "the business of America is business." Such an approach did much to reenergize the entrepreneurial spirit that had flourished in the earlier part of the century, and as a result, while in some respects the decade saw a consolidation of the earlier advances—despite the rollback of many

of the governmental innovations that had characterized the Progressive Era—the nation continued to see new inventions and advancements over the course of what would come to be known as the “Roaring Twenties.”

Nowhere was the roar louder than on the nation’s streets where the many automotive developments of the first part of the century had created a car culture that had seen the number of vehicles balloon from the 8,000 cars that had been registered in the United States in 1900 to the 9 million that were on the books by 1920. But that was only the beginning, as that number would more than triple during the 1920s, reaching 29 million by 1929. In conjunction with that growth was the development of the now much-needed traffic lights that arrived in 1920. For drivers, the 1920s saw their driving experience enhanced with the development of power steering, the introduction of the convertible, and the headrest. Meanwhile, for those lucky enough to have a garage, the development of the garage door opener offered protection from the elements once the driver arrived home. Meanwhile, in response to the still-growing car culture, the 1920s saw the opening in Dallas, Texas, of the first drive-in restaurant, an innovation that would only grow in future years.

One did not need to hit the road to benefit from the developments of the postwar era. Health-related advances included the introduction of Q-tips and Band-Aids as well as the audiometer, which helped measure hearing loss. That development was complemented by the development of the hearing aids whose need was often revealed by the device. Homeowners had their lives made easier by the introduction of the bread slicer, the garbage disposal, and the hair dryer. And, of course, the invention of the bulldozer and the pressure washer enhanced both the development and maintenance side of the ever-growing home-building industry.

With the increasing amount of leisure time that many of these developments afforded the citizens of the 1920s, people were able to enjoy new advances in entertainment and recreation. The development of waterskiing as well as sunglasses added a new dimension to life out of doors, as did the new jungle gym and monkey bars that appeared in public parks. And

of course, all of it was made better by the ice cream treat the Eskimo Pie, which debuted as the decade opened. The movie industry also continued to grow and thrive with the development of the Moviola, a device that allowed for watching and editing at the same time, enhancing the production process. But for movies, the truly big development of the 1920s was the introduction of the “talkies” with Al Jolson’s *The Jazz Singer*, premiering in 1927, being the first feature-length sound picture in cinema history. It was a revolutionary development that, like Charles Lindbergh’s transatlantic airplane flight and Babe Ruth’s record 60 home runs, both in that same year, served to reaffirm the singular American spirit that had been evident in so many ways since the turn of the century. Indeed, new advances in business, the arts, and technology—in virtually all areas of human endeavor—had left the United States in a position of unparalleled prosperity while looking to the future with unbridled optimism.

And yet, despite these unprecedented advances, the impact of which would continue to resonate for years to come, the “Roaring Twenties” would, in fact, finish with a resounding thud, marked by the stock market crash of late October 1929 that sent the nation into a financial and psychological tailspin. Indeed, for Americans, the good times that been evident on so many fronts came, suddenly and without warning, to a crashing halt as the 1920s limped into the 1930s and the once seemingly invincible nation was forced to confront an unprecedented economic reversal.

William H. Pruden III

Further Reading

- Constable, George, and Bob Somerville. 2003. *A Century of Innovation: Twenty Engineering Achievements That Transformed Our Lives*. Washington, D.C.: Joseph Henry Press.
- Diner, Steven J. 1998. *A Very Different Age: Americans of the Progressive Era*. New York: Hill and Wang.
- Gordon, Robert J. 2016. *The Rise and Fall of American Growth: The U.S. Standard of Living since the Civil War*. Princeton, NJ: Princeton University Press.

Aerosol Spray Can

Aerosol is a chemical mixture of fine solid particles that an aerosol spray can disperses by spraying the mixture into a mist of liquid particles.

The idea for aerosol spray cans can be traced to 1790 when the French began carbonating beverages. Norwegian chemical engineer Erik Rotheim of Oslo can be credited for patenting the first aerosol spray can in 1927.

The modern spray can was invented in 1941 by Americans Lyle Goodhue and William Sullivan. The American Department of Agriculture contacted the two scientists to make a more efficient and production-friendly version of Rotheim's invention. The men designed a refillable spray can intended for soldiers to kill malaria-infested bugs such as mosquitoes during World War II. The can was pressurized with liquefied gas, which gave it the ability to be sprayed with even dispersion.

In 1974, Drs. Frank Sherwood Rowland and Mario J. Molina discovered that the chlorofluorocarbons (CFCs) used in these spray cans were causing harm to the earth's ozone layer. CFCs have since been replaced with safer chemicals since the U.S. Congress passed the Clean Air Act in 1977.

In the 20th and 21st centuries, many artists used aerosol spray paint to create graffiti art.

Sebastian Gottwald

See also *Vol. 1, Sec. 2: Vapor-Compression Refrigerator; Vol. 3, Sec. 1: Chlorofluorocarbons (CFCs)*

Further Reading

Zimmer, Lori. 2017. *The Art of Spray Paint: Inspirations and Techniques from Masters of Aerosol*. Beverly, MA: Rockport.

Airplane

The airplane, which revolutionized travel, was a product of research and experimentation. Although people had always been fascinated by the idea of human flight, few believed it to be possible or practical. Over the years, innovators and inventors sought to conquer

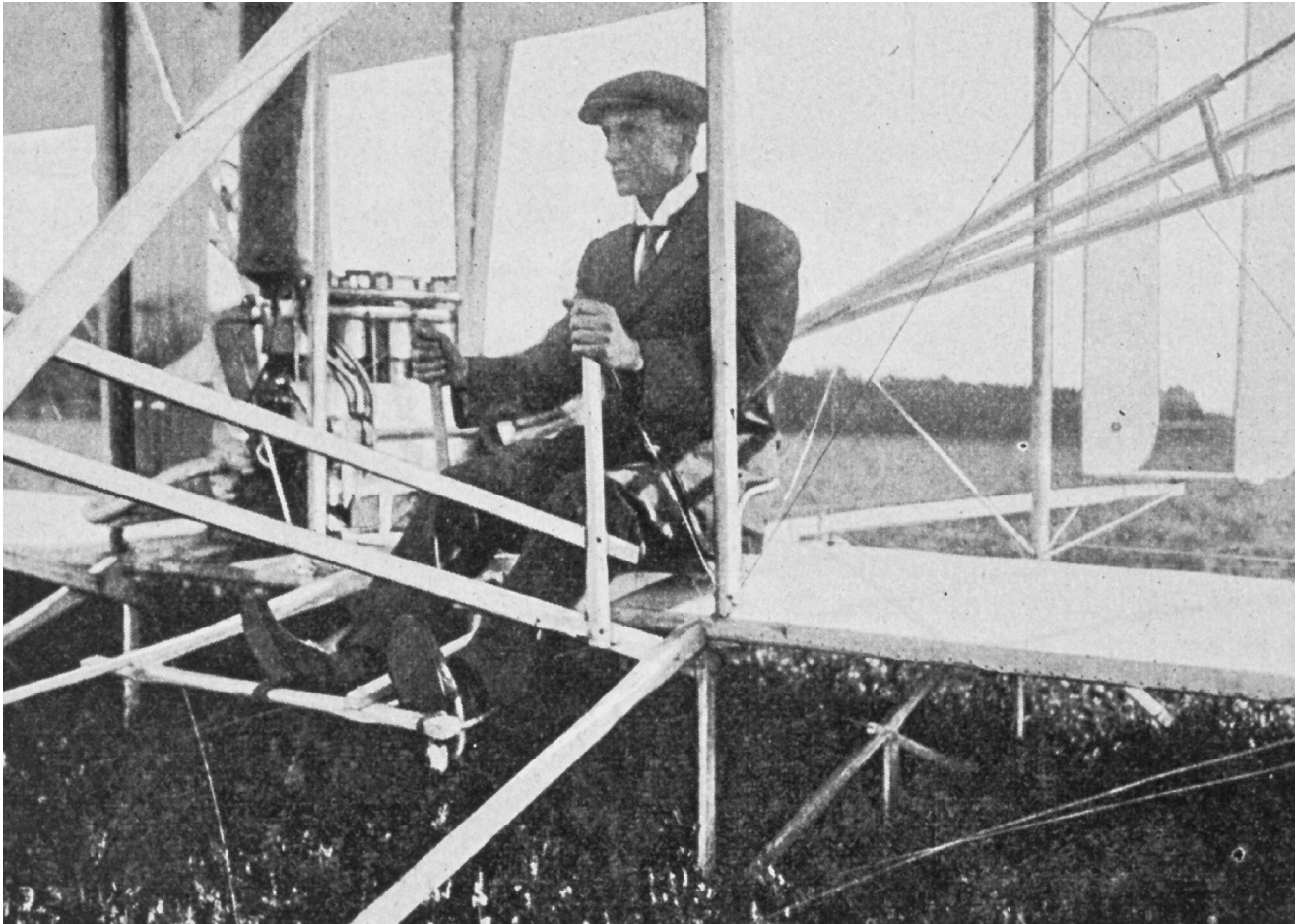
the skies in different ways. Thanks in great part to the innovations made by Orville Wright (1871–1948) and his brother Wilbur Wright (1867–1912), motorized air travel became commonplace in the military during World War I (1914–1918) and then the public sector during the later 1940s. Airplane technology was based on old discoveries and inventions, and it led to new discoveries and inventions.

An ancient Greek myth told the story of Icarus, who made wings of feathers and wax and fell into the sea when he flew too close to the sun and his wings melted. One interpretation of the myth is that humans were not meant to fly. But flying continued to fascinate humankind. During the 15th century, Leonardo da Vinci drew sketches of impractical human-powered flying machines. His ideas, which he never experimented with physically, were almost exclusively based on his observations of nature and theory. For example, da Vinci erroneously believed that it was the flapping of wings that were the key to human flight.

The first great leap in human air travel occurred in 1782, when the Montgolfier brothers from France invented a hot air balloon that floated over Paris for 25 minutes. The Montgolfier balloon floated because the hot air inside it was lighter than the cold air around it. Although hot air balloon technology suffered from limited maneuverability, it offered humans the ability to look down from the sky for the first time. Under a hundred years later, Union forces in the American Civil War (1861–1865) sometimes used hot air balloons to collect information about Confederate troop movements.

During most of the 1800s, Europeans experimented with heavier-than-air craft with curved wings that harnessed the upward force (lift) of natural airflow. Sir George Cayley designed the first glider in the early 1800s. By the end of the 1800s, Otto Lilienthal had experienced limited success with his glider designs. Most glider flights were brief and dangerous, because the craft suffered from limited maneuverability and usually ended in crash landings. In 1896, Lilienthal died in a glider crash.

After reading about Lilienthal's death and details about his invention in the newspaper, Orville and Wilbur Wright, lifelong inventors who ran a bicycle shop with their sister Katherine, drew up a three-part



An unnamed pilot works the controls of a Wright Flyer in 1909. After inventing the airplane in 1903, brothers Orville and Wilbur Wright traveled the country demonstrating the product to potential consumers by training pilots and offering rides. Their sister Katherine often flew as a passenger to illustrate the safety of this new mode of transportation. (National Oceanic and Atmospheric Administration)

plan to design a practical flying machine. First, unlike balloons that relied on hot air to become airborne, a practical flying machine, they thought, would use the natural airflow that was already available to provide lift. Second, unlike hot air balloons and gliders that went where the wind blew them, a pilot had to be able to control the machine at all times. Third, for the craft to remain in the air for extended lengths of time, it had to be powered by an engine.

With their plan in hand, the brothers spent several years conducting research by reading books and magazines on the subject. They even borrowed books from the Smithsonian Institution in Washington, D.C. They learned about the designs of flying machines that had already been built and tried. Like da Vinci, they also observed birds in flight, and they saw how the birds

twisted their wings slightly to maintain balance. They realized that balance was a key to flying. One day while working in their bicycle shop, Wilbur got an idea while handling a long, empty box. He realized that the wings of an aircraft could be twisted in the same way as a box. Based on this realization, the brothers designed a five-foot kite with two wings (a biplane). The experiment worked. They found that by tugging at the corners of the airborne kite with ropes, they were able to twist (wing-warp) the edges of the wings and keep the kite in balance and under their control.

After the success of this model, the brothers designed a 17-foot prototype to conduct a manned experiment. The focus had primarily been on wing design instead of pilot comfort, and the design of this

plane required the pilot to lie on top of a wing. The brothers examined records of weather patterns from around the country in an attempt to find an area in the United States with steady winds. In 1900, they traveled with their prototype to Kitty Hawk, North Carolina, because it was a windy and desolate area replete with sand dunes to cushion landings. The experiments they conducted that year and the following year convinced them that the prototype design did not generate adequate lift.

They began to question the data that previous inventors had collected, and they decided to conduct their own wind tunnel experiments to simulate flying conditions. In 1902, after collecting their own flight data, the brothers returned to Kitty Hawk with a redesigned aircraft. The new machine had longer, narrower wings and a fixed tail. Lift was greatly improved, but the fixed tail made the craft less maneuverable. So they redesigned the tail to have a movable rudder. The addition was a tremendous leap forward in airplane technology. Pilots could now make the craft roll (bank so that one wing is up while the other is down), pitch (move the nose up or down), and yaw (turn the aircraft left or right). By redesigning the wings and including both wing warping and rudder controls, the brothers had achieved their first two goals in their three-part plan.

On December 17, 1903, at Kitty Hawk, Orville flew the *Flyer* with the power of a mounted light-weight engine. The airplane stayed in the air for 12 seconds and flew for 120 feet. On a fourth attempt that day, Wilbur flew for 59 seconds and reached a distance of 852 feet. In 1904, Orville flew the *Flyer II* in a complete circle around Huffman Prairie in Dayton, Ohio. After adding some more weight to the front of the *Flyer III*, in 1905, Wilbur flew for 24 miles and landed after 39 minutes of flight—but only because the engine had run out of fuel.

Having fulfilled the third part of their plan, the brothers filed for a patent for their invention and received one in 1906. The Wrights wanted to go into the business of airplane manufacturing and sales, but most of the public still had doubts about the possibility of human flight. Few had witnessed the historic first motorized flight in 1903, so the brothers made plans to expose more people to their invention. In 1909, the Wright brothers became national heroes after Wilbur

flew over New York during the Hudson-Fulton celebrations and millions of people witnessed human flight for the first time. They were introduced to kings and queens of Europe. U.S. president Howard Taft gave them an award at the White House, and their hometown hosted a carnival and a fireworks display in their honor.

As early as 1908, the U.S. and French governments showed interest in purchasing airplanes from the brothers. The Wrights built two airplanes with pilot seats included, and Orville demonstrated the invention in Washington, D.C., while Wilbur did the same in France. Unfortunately, one of Orville's demonstrations ended with the death of Lt. Thomas Selfridge, the first person to be killed in an airplane. However, the accident did not deter military interest in airplanes. In fact, during World War I, engineering and manufacturing teams greatly improved the airplane's design and capabilities. By the end of the war, American factories had produced more than 15,000 airplanes for military use. From that time, Boeing in Seattle and Washington and Lockheed in Santa Barbara, California, among others, became leading aircraft producers.

However, even though many people recognized the military uses of airplanes, in the first part of the 1900s, few civilians believed that they had practical nonmilitary uses, because they were viewed as too dangerous. In 1927, Charles Lindbergh flew his small airplane, the *Spirit of St. Louis*, safely across the Atlantic Ocean. The event transformed Lindbergh into a national hero, and it went a long way in convincing people of the airplane's viability as a mode of public transportation. The airline industry had a slow start, beginning in 1914 with one passenger.

By 1940, statistics showed that air travel was becoming safer, and the nonmilitary effects of the airplane included the creation of a mass transit system that was quicker than any other form of travel. Airlines began offering flights to different parts of the continental United States. One company, Pan American Airlines, was the first to offer international flights. Ultimately, airplane technology led to a more connected world, and advancements in airplane technology led directly to the development of jet, rocket, and space technologies.

Rolando Avila

See also Boeing, William E.; *Vol. 2, Sec. 1*: Wright, Wilbur and Orville; *Vol. 2, Sec. 3*: Helicopter; Military Technology (World War II)

Further Reading

Bilstein, Roger E. 2001. *Flight in America: From the Wrights to the Astronauts*. 3rd. ed. Baltimore: The Johns Hopkins University Press.

Kirk, Stephen. 1995. *First in Flight: The Wright Brothers of North Carolina*. Winston-Salem, NC: John F. Blair.

McCullough, David. 2015. *The Wright Brothers*. New York: Simon & Schuster.

Anderson, Mary (1866–1953)

Alabama native Mary Anderson is credited with the invention of the windshield wiper. Anderson stumbled upon this idea on a cold winter's day in New York City. Even though her invention revolutionized standard equipment in cars, she never profited from it.

Anderson was born on February 19, 1866, in Greene County, Alabama. Her father died when she reached the age of four, so she, her sister Frannie, and their mother moved to Birmingham, Alabama, and lived there until she reached the age of 27. In the early 19th century, Anderson had gone to explore New York City. On a cold day in winter, while riding in a trolley, she observed how the motorman had to completely stop the trolley, get out, and wipe away the snow manually.

When she returned to Alabama, she immediately began designing a device that would mechanically wipe the windows of motor vehicles without anyone having to get out of them. In 1903, Anderson had her model manufactured. Several companies scoffed at her invention, claiming it would only distract the driver. Her patent expired before she was ever able to market her invention.

Unsuccessful, Anderson returned home to be with her mother, sister, and brother-in-law. There, she managed the apartment building in which she lived. She died on June 27, 1953, in her summer home located in Tennessee.

Rolando Avila

See also Automobile Technologies (Pre–World War II)

Further Reading

Leeper, Angela. 2014. “The Woman Who Invented Windshield Wipers: Mary Anderson and Her Wonderful Invention.” *Booklist* 110, no. 15: 77.

Olive, J. Fred, III. 2010. “Mary Anderson.” *Encyclopedia of Alabama*. March 9. <http://www.encyclopediaofalabama.org/article/h-2553>, accessed August 29, 2018.

Assembly Line

One of the continuing myths of American industrial history is that Henry Ford invented the assembly line. The roots of the assembly line actually go back to the Arsenal of Venice in the 1400s. Adam Smith, in his *Wealth of Nations*, had outlined the idea of labor specialization, which is basic to the assembly line. It can be said that Ford Motors made the assembly line operational and economical, but a lot of credit must go to Charles Emil Sorensen, a production genius and a loyal lieutenant of Ford. Sorensen was the mastermind behind the assembly line at Ford's Highland Park plant in Michigan. Even Sorensen, however, cannot take full credit, as it was a team of Ford managers that worked out the system.

The assembly line was created out of the crafts system as production requirements increased. Each car was originally built as a single unit by a team of mechanics. In 1910, there were over 200 manufacturers across the United States. Oldsmobile had the best factory, with a production of over 3,000 cars per year. Ford always had the dream of selling a car for the masses, but in 1910, he was bunched with all the other producers, with no cost advantage.

The Highland Park assembly line really began with the inefficiencies of the second Ford plant at Piquette Avenue, which was bigger than the first Mack Avenue plant that Ford left in 1904, but little thought, other than as to size, had been put into the layout. The cost of the 1904 Piquette plant was \$76,000. There were several buildings, requiring a lot of material and subassembly handling. The main focus at the Piquette plant was product development, which laid the groundwork

for the 1908 launch of the Model T. As noted, autos, in general, were hand built using the crafts method prior to Highland Park.

Generally, the crafts method had cars being built in stalls, with parts being brought to the car. Using the crafts system, one to two cars could be produced in a day at best. Ford's second plant at Piquette took production to over 14,000 a year, which was believed to be the limit of the crafts method. The base cost was around \$600 to \$800. Ford started to design a new plant to achieve his dream of a car for the masses. Solving the inherent problems were paramount when, in 1907, Ford started to plan the Highland Park plant to make the Model T.

Ford hired an experienced industrial architect in Albert Kahn, who had designed the 1903 Packard Motor Car Company plant in Detroit. The Highland Park plant was composed of two separate, four-story assembly buildings. The buildings were designed logically: raw materials were delivered to the top floor, and as finished parts were forged and machined, they made their way down the floors through more than 1,000 openings. Ford and Kahn had incorporated the use of gravity for chutes, conveyors, and tubes. The plant was designed to efficiently take in and distribute boxcars of supplied parts. But in 1910, the new assembly plant struggled to make 19,000 cars. It was far from an assembly line then, but it had the best materials-handling system in the world.

Even for Ford Motor Company, the assembly line was more of an evolution. Sorensen noted, "The essential tools and the final assembly line with its many integrated feeders resulted from an organization which continually used experimenting and improvising to get better production."

One key advance was the conveyor system to bring radiators to the main line. Before that, radiators had been moved by hand and muscle from the docks to the line. Gravity chute conveyance systems were designed and modeled after those in food factories such as those of Busch Beer in St. Louis and H. J. Heinz in Pittsburgh. Kahn and Ford found the gravity conveyance system so efficient that parts plants were built up to 10 stories high to take full advantage. However, Ford slowly learned that one-floor conveyor systems worked better. Conveyors started to be used for other parts and subassemblies.

Assistant superintendent Clarence Avery achieved another key advance. Experience allowed Avery to work out the timing schedules of each operation of the assembly line, which was necessary before installing conveyor assembly systems for motors, fenders, magnetos, and transmissions. Next, Ford had to standardize parts from his supply chain using blueprints. Supply chain development played a critical role in full implementation of the assembly line process. Ford Motor was able to cut manufacturing costs by 50 percent over a two-year period by implementing these types of improvements.

Ford didn't apply the integrated assembly line system until April 1913, when the company used it to build flywheel magneto assemblies for the Model T. Ford then moved to an assembly line for crankshafts. Conversion of the Highland Park plant to the assembly line method started in 1913. Prior to this, Ford had been using an intermediate phase of 50 workstations. It took an estimated 12.5 man-hours to build a car. In 1913, Ford moved the chassis to a single chain-pulled line, which cut the time to about nine man-hours. Within a year, Ford doubled production and cut the cost in half. Employment went to 13,000 in 1914 as the total investment at Highland Park went over \$200 million. The doubling of production in 1913 created a new problem, though: jobs had been specialized to the point that Adam Smith had hailed as revolutionary.

The problem was that the boring, routine work caused absenteeism to reach over 10 percent and turnover more than 300 percent! Human issues were now the limitation rather than technology. Ford's solution was to double the wage to five dollars a day, which worked. Costs came down, and the production rate hit a car every three minutes. The wage of five dollars a day did have restrictions, as Ford tried to select the best assembly workers. The requirements included that a man should be married or a woman should be the sole supporter of a family, which Ford felt was necessary for productive work. Ford also required that a person have "thrifty habits." He went as far as implementing a sociological department to monitor employees and help them develop thrift and family values. By the end of 1914, Ford had an amazing cost advantage over his competitors. He had no competition for cars priced under \$500.

Quentin R. Skrabec

See also Automobile Technologies (Pre–World War II); Ford, Henry; General Motors (GM)

Further Reading

Brinkley, Douglas. 2003. *Wheels for the World: Henry Ford, His Company, and a Century of Progress*. New York: Viking.

Olsen, Byron, and Joseph Cabadas. 2002. *The American Auto Factory*. St. Paul, MN: MBI.

Sorensen, Charles. 2006. *My Forty Years with Ford*. Detroit: Wayne State University Press.

Primary Document: Excerpt from Henry Ford's "The First Assembly Line" (1913)

In 1913, Henry Ford wrote an essay titled "The First Assembly Line." In the excerpt here, he describes how assembly lines could be used to build automobiles that the ordinary person could afford.

A Ford car contains about five thousand parts—that is counting screws, nuts, and all. Some of the parts are fairly bulky and others are almost the size of watch parts. In our first assembling we simply started to put a car together at a spot on the floor and workmen brought to it the parts as they were needed in exactly the same way that one builds a house. When we started to make parts it was natural to create a single department of the factory to make that part, but usually one workman performed all of the operations necessary on a small part. The rapid press of production made it necessary to devise plans of production that would avoid having the workers falling over one another . . .

The first step forward in assembly came when we began taking the work to the men instead of the men to the work. We now have two general principles in all operations—that a man shall never have to take more than one step, if possibly it can be avoided, and that no man need ever stoop over.

. . . In short, the result is this: by the aid of scientific study one man is now able to do somewhat more than four did only a comparatively few years ago. That line established the efficiency of the method and we now use it everywhere. The assembling of the motor, formerly done by one man, is now divided into eighty-four operations—those men do the work that three times their number formerly did.

Source: Ford, Henry, in collaboration with Samuel Crowther. 1922. *My Life and Work*. Garden City, NY: Doubleday, Page.

Automobile Technologies (Pre–World War II)

An automobile is a wheeled passenger vehicle powered by a motor. It is designed to run on roads and generally has four wheels. The mass production automobile industry was born in the 1910s. Automobile history is often divided between the periods before and after World War II. Pre–World War II automobiles comprise a distinct stage that eventually led to the automobile revolution after the end of World War II. Automobile historians qualify the period between World War I and the Great Depression (1918–1929) as the Vintage Era. The 1930s are known as the transitional phase of the

automobile industry. From the improvements to design to the introduction of the assembly line, hydraulic brakes, the V8 engine, the fender, and more, this was a period in which automobiles went from being luxury items to common conveyances.

The earliest automobile history lies in Germany. In 1870, German Jew Siegfried Marcus designed and built the first two-cycle internal combustion engine. Ten years later, he built a four-cycle engine. In 1885, Karl Benz produced the first gasoline-powered automobile.

In 1903, Henry Ford introduced the Model A, a two-seat runabout with a two-cylinder, eight-horsepower engine that he sold for \$750. In the first decades of the 20th century, gasoline-powered engines

gradually overtook steam-powered engines, first for passenger cars and later for farm vehicles and trains.

The 1910s saw a huge expansion of different companies competing against each other. This led to a variety of automobile designs. Hudson Motor Car Company, Nash-Kelvinator Corporation, Studebaker Corporation, and Crosley Motors are just a few such companies. The 1920s was a period of immense innovation and experimentation to see what sold and what did not. This robust competition faltered at the end of the 1920s, when the stock market crash of 1929 heralded the beginning of the Great Depression.

In 1913, Henry Ford innovated the moving-chassis assembly line, allowing for automobiles to be produced at a rapid pace. This manufacturing technique made it possible to make relatively affordable cars. Ford's Model T became the first automobile to be rapidly produced using this method, becoming the car that most people could afford.

The Model T is generally seen as the true start of the automobile era. The Model T went from \$850 in 1908 to \$300 by 1925 as Ford's assembly line technology improved. As prices dropped, the number of cars sold rose. In the Vintage Era, over 15 million Model Ts were built and sold. While the Model T automobile was not particularly technologically innovative or impressive, it did allow for the mass consumption of automobiles. Although it was not until after World War II and the rise of suburbia that automobiles became seen as a necessity for most people, the popularity of automobiles began with the Model T.

Besides the assembly line, Ford is also credited with the improvement of the V8 engine. The V8 engine is an eight-cylinder combustion engine—hence the name. It allowed automobiles to go at higher speeds while running smoother than previous engines.

General Motors first started using this engine in the United States in 1916 in its Oldsmobile. The problem with the engine at the time was its price—it was too expensive to be placed into affordable cars, eventually leading General Motors to favor cheaper engines. From the start of 1922, Ford tackled making a cheaper V8 engine using his competitor's V8 engine vehicles as models. In 1932, Henry Ford introduced the first mass-produced monobloc V8 engine as an improvement to previously existing V8s. Between March and

December of that year, Ford was able to produce over 12,000 V8 engines. While it was not a perfect design, with a majority of its original versions needing fixes due to technical issues, it did eventually lead to vehicles that were able to travel much faster and cheaper than before. Much of Clyde Barrow's (of Bonnie and Clyde fame) success as a bank robber and getaway driver stemmed from the fact that he used Ford V8s while law enforcement used vehicles with smaller, slower engines.

The addition of radios into automobiles was introduced to the United States by Paul Galvin in 1930. Galvin's Manufacturing Corporation faced closure during the Great Depression, so he looked for some invention that could revitalize his business. The company invented the first car radio. Galvin could not afford to advertise, so he simply installed radios in cars and had employees drive around with the volume turned up. Galvin succeeded, and his company later was renamed Motorola—a combination of “motor vehicle” and “Victrola.” Motorola would eventually become one of America's largest communication companies.

Automobile brakes became much safer in the 1920s. The innovation of four-wheel braking mechanisms gradually became standard on most automobiles. In 1919, Malcolm Loughead invented hydraulic brakes, which became the standard at most companies, though Ford refused to switch to them at least until 1939. Hydraulic brakes are placed on each wheel so that when the brake pedal is pushed, fluid transfers to the pistons and then immediately to the brakes themselves. This system meant that automobiles could stop easier when going at top speed, an important innovation at a time when engines were becoming larger and more powerful. Beginning as a luxury car add-on, hydraulic brakes became widespread in automobiles near the end of the 1920s.

Early automobile bodies were first modeled on carriage bodies (thus the name “horseless carriage”), with fully or partially open bodies. Automobiles started to take the form of closed-body cars with a top and windows for more security and protection from the weather. By the late 1920s, almost all cars were closed body.

As closed-body cars gained popularity, the glass in the windows had to be reinforced. The first windowed automobiles turned deadly in crashes when the glass shattered, causing shards to fly all over. Innovations in

safety glass began to take shape in the 1920s. Two European inventors, Edouard Benedictus and John C. Wood, discovered a way to stop glass from shattering into pieces by creating laminated glass, or Triplex glass, named for their company established in 1923. Triplex glass was made from two pieces of glass with a resin laminated between them. Rather than splitting into a million deadly pieces, the glass would form a spider web–like pattern that we still see today in broken or cracked automobile glass. The late 1920s saw the spread of this safety glass as an add-on. It was not until 1937 that safety glass became mandatory for all car models.

Fenders on an automobile's front, rear, and side bumpers were invented in 1901 by Frederick Simms. However, it was not until the 1920s that fenders started to play a bigger role. In 1927, Harley Earl brought the notion of expanding the fenders to General Motors to allow a spare tire to be mounted on the side of a car, snugly supported on the fender itself. While Earl did not come up with the side-mounted tire first, he did refine it, placing it where it did not interfere with car doors. Major fender designs from the 1930s included the skirted fender and the “Y Job” fender, both designed by Earl. The year 1933 saw the introduction of the skirted fender, named for how it covered the wheels like a skirt. 1938 saw the Y Job automobile, with its new fender design being a part of the body, paving the way for how fenders would be designed in the postwar era.

The “Big Three” U.S. automobile makers, General Motors, Ford, and Chrysler, rose to prominence during the Great Depression in the wake of the collapse of smaller car companies. While the Big Three were not the only companies to survive the crash, they were the strongest, leading the way in innovations and sales. Many of their competitors eventually closed their doors.

From great advances in automobile technology to the growth of the major automobile companies, the Vintage Era had laid down the basis of automobiles to come. There would be only growth in the industry after World War II came to a close.

Alejandro Esparza

See also Assembly Line; Ford, Henry; General Motors (GM); *Vol. 3, Sec. 1: Automotive Technologies (Post–World War II)*

Further Reading

- Car: The Definitive Visual History of the Automobile.* 2011. New York: DK.
- Glancey, Jonathan. 2013. *The Car: The History of the Automobile.* London: Carlton Books.
- Nahum, Andrew. 2009. *Fifty Cars That Changed the World.* London: Conran Octopus.
- Parissen, Steven. 2014. *The Life of the Automobile: The Complete History of the Motor Car.* New York: St. Martin's Press.

Bakelite

“Polyoxybenzylmethylenglycolanhydride,” more commonly known as Bakelite, is a material so innovative and useful that it has affected the lives of millions of people. Bakelite, a type of plastic, evolved into a seemingly infinite variety of mechanical parts, jewelry, consumer goods, packaging, construction materials, electronics, medical devices, sporting goods, and transportation and agricultural tools. Dr. Leo Hendrik Baekeland invented Bakelite in 1907.

Leo Hendrik Baekeland was born in Belgium on November 14, 1863. During his high school years, he also attended evening courses at the Ghent Municipal Technical School. In 1884, he graduated *maxima cum laude* with a doctorate in science from the University of Ghent at the age of 21. He married Celine Swarts, his professor's daughter, and they traveled to the United States in 1889. He worked as a Yonkers New York chemist for E. and H. T. Anthony and Company, manufacturers of photographic equipment, but resigned in 1893 to form Nepera Chemical Company. With his new venture, Dr. Baekeland invented a new photographic paper called Velox that could be developed with artificial gaslight. Previous versions of photo paper required indirect sunlight for development, which was inconvenient on cloudy days. The Eastman Kodak company reputedly paid Dr. Baekeland \$1 million for the Velox patent. With this new wealth, Leo and Celine purchased an estate in the New Harmony section of Yonkers, where he set up his own laboratory with an assistant, Nathaniel Thurlow.

Bakelite owes its existence to two earlier key discoveries in chemistry. In 1834, Friedlieb Ferdinand



A radio from the 1950s made from Bakelite, a synthetic resin invented in 1907 and used to make a variety of products. Bakelite fell out of use after the invention of polymer products with more practical and improved properties. (DEA/A. DAGLI ORTI/De Agostini/Getty Images)

Runge extracted phenol (C_6H_6O) from coal tar. Twenty-five years later, Alexander Mikhailovich Butlerov was the first to report on the presence of formaldehyde (CH_2O), which resulted from his attempt to synthesize methylene glycol. Later, German chemist Adolf von Baeyer and his student Werner Kleeberg conducted several experiments combining phenol with formaldehyde and reported a hard, insoluble material that ruined their laboratory equipment. At the beginning of the 20th century, several chemists were working on phenol-formaldehyde resins, but none were successful in creating a useful product.

Baekeland and Thurlow wanted to develop a synthetic resin as a substitute for shellac, a popular coating derived from the secretions of the female lac bug,

Kerria lacca. The resulting material, called Novolak, was not commercially successful. They changed the direction of their research toward finding a resin that would strengthen wood rather than simply coat it. To perform the new experiments and confirm the results, they used a specially designed steam-pressure vessel that became known as the Bakelizer. By combining phenol and formaldehyde in this vessel without a catalyst, they were able to produce a new resin that was easily moldable at high temperature and pressure but solid at room temperature. It was also highly resistant to chemical solvents, heat, and electrical current. In his laboratory notes, Leo called the new material “Bakelite.”

Leo Baekeland obtained 400 patents for the manufacture and applications of Bakelite. In 1910, he

formed a U.S. company to handle marketing and manufacturing of the material for electrical insulators. In 1930, the Bakelite Corporation occupied 128 acres in Bound Brook, New Jersey. Eventually, other plastics emerged with improved properties (e.g., more color options), but Bakelite was the first material to demonstrate the wide applicability of polymer science.

Peg A. Lamphier

See also *Vol. 1, Sec. 3: Vulcanization*

Further Reading

- Bijker, Wiebe E. 1997. *Of Bicycles, Bakelite and Bulbs: Towards a Theory of Socioeconomic Change*. Cambridge, MA: MIT Press.
- “New Chemical Substance.” 1909. *The New York Times*, February 6.
- Powers, Vivian. 1993. “The Bakelizer.” *American Chemical Society* (November 9): 1–8.
- “Science: Father of Plastic.” 1940. *Time*, May 20.

Band-Aid

Band-Aid is a brand best known for popularizing adhesive bandages, which typically consist of a square piece of gauze adhered to a strip of tape. The tape secures the gauze over a small wound to keep it sterilized and protected.

An employee of pharmaceutical giant Johnson & Johnson, Earle Dickson, created Band-Aid brand adhesive bandages in 1920. Dickson was a cotton buyer for the company. Josephine Knight, Dickson’s wife, frequently scraped her hands and arms while cleaning their house and cooking. Dickson tried to cover her wounds with gauze secured with tape, but the bandages always fell off when Knight resumed her housework. Eventually, Dickson invented what would soon become known as a Band-Aid. He cut the gauze into squares and evenly spaced them out on a roll of tape. The gauze was held in place on the tape by using crinoline. Crinoline, which is a horsehair-and-cotton blend fabric that maintains its rigidity, was commonly used to shape women’s dresses and other clothes. Dickson’s handmade adhesive bandages were a success. They kept his wife’s extremities safe from

reinjury, and she no longer required her husband’s assistance to dress her wounds.

Dickson shared his idea with his boss James Wood Johnson, who decided to mass-produce it. When Band-Aids were first introduced on the market, they failed to sell because they were handmade using the resources available in the 1920s—a time of nationwide financial stress when people could not afford to spend their money on fancier bandages. However, Johnson & Johnson continued to manufacture Band-Aid bandages and eventually created a machine to produce a more sterilized version of the previously handmade product. Sales started to rise slightly over the next decade. In 1938, a method to produce completely sterilized bandages was implemented. In 1942, the popularity of Band-Aid brand finally exploded, when millions of them were shipped overseas as part of the World War II war effort.

In a patriotic response to their new rise in sales, Johnson & Johnson introduced the first decorated adhesive bandages, known as “Stars and Strips,” in 1956. This trend of colorful bandages targeted toward the young at heart continued well into modern culture, featuring beloved designs such as Mickey Mouse, Barbie, smiley faces, Spider-Man, and Hello Kitty. Band-Aid variations have continued to come out over the following years; sports, sheer, antibiotic, and liquid bandages were all created to meet customer’s changing needs. These have been further popularized through celebrity endorsement via commercials by the likes of American icons such as John Travolta, Brooke Shields, and Teri Garr. Band-Aid has solidified itself as a household name.

Brenna Biggs

See also *Vol. 1, Sec. 3: Adhesive Tape*

Further Reading

- Marks, Susan. 2007. *Stuck on You: The Indispensable History of Band-Aid Brand Bandages*. Portland, OR: Collectors Press.

Bell Telephone Laboratories

Bell Telephone Laboratories (typically referred to as Bell Labs) has achieved many technical innovations,

with the most notable being the transistor—which had numerous applications such as in telephone lines, radios, and hearing aids. The transistor developed by Bell Labs was the precursor to the complex system of transistors present on chips in modern electronics. Other advancements from Bell Labs were precursors that greatly impacted modern technology such as the first hi-fi audio recording system, films with audio tracks, silicon solar cells, fiber-optic data cables, and the first cell phone system.

Since its formation in 1925, Bell Telephone Laboratories served as a center of innovation where numerous advancements were made. The American Telephone and Telegraph Company (AT&T) established the organization as an autonomous research-and-development company complementary to the telephone company and manufacturer Western Electric, which was also a subsidiary of AT&T. Bell Labs collaborated with the other two companies to have sufficient channels of communication to efficiently control the process of design, development, and manufacturing.

For decades, Bell Laboratories was very successful. Dr. James Fisk, who was the head of Bell Labs from 1959 to 1974, attributed the success to three essential areas: people, purpose, and environment. For the laboratory to produce the best and most innovative work, it needed the best minds. It was important to recruit the finest employees, so hundreds of lab employees visited numerous colleges and universities annually to do so. The interview process was comparatively slow, taking days. Prospective employees visited the lab to meet and speak with their possible colleagues.

Leaders kept the purpose of Bell Labs broad enough to provide sufficient freedom and space for creativity; the main purpose was to innovate and improve upon areas of interest for the parent companies, AT&T and Western Electric. Employees at the lab were given a high level of autonomy where, aside from an approval process, the progress of a project was lightly monitored and employees could extend their research into long periods, even years. In addition to offering virtually unfettered access to the tools necessary for research, Bell Labs also held programs and seminars to keep employees informed of the latest

technological developments. The lab also allowed employees the freedom to publish their findings as long as they did not endanger company-held patents. The lab had its own well-respected publication: *Bell System Technical Journal*.

The environment of Bell Labs was organized so that scientists and researchers from different fields could collaborate under one roof. Many of the facilities were located in the parent companies' manufacturing plants, where scientists could convey what they had learned from their research with engineers who could use the information for practical applications. Additionally, many top scientists worked at the labs, which maintained an open-door policy so that fellow employees could seek the necessary expertise or opinion on a topic.

Rosanne Welch

See also Vol. 2, Sec. 1: American Telephone and Telegraph Company (AT&T)

Further Reading

Gertner, Jon. 2012a. *The Idea Factory: Bell Labs and the Great Age of American Innovation*. New York: Penguin Press.

Gertner, Jon. 2012b. "True Innovation." *The New York Times*, February 25.

Mabon, Prescott C. 1975. *Mission Communications: The Story of Bell Laboratories*. Murray Hill, NJ: Bell Telephone Laboratories.

Binney & Smith Inc.

New Yorkers Edwin Binney and Harold Smith, inventors of the Crayola crayon, founded Binney & Smith Inc. in 1855. In 1860, Joseph Binney, Edwin's father, emigrated from England to the United States and founded Peekskill Chemical Works. The company made lampblack and ground charcoal. Edwin Binney inherited Peekskill Chemical Company from his father in 1885.

Responding to complaints that chalk was messy to write with, Binney invented a dustless chalk by mixing talc, cement, and ground slate. In 1902, he presented his chalk innovation at the St. Louis World's

fair, where he won a gold medal. The same year, he founded Binney & Smith Inc. with his cousin Harold Smith. Initially, the company produced carbon black, a substance found in gas deposits and used in printing ink, shoe polish, and black crayons.

In 1903, the company produced a “Staonal Marking Crayon” before inventing the wax markers that came to be known as crayons. Binney proved the innovator in the company, while Smith functioned as the company salesperson, promoting products that became national best sellers. Binney & Smith marketed the crayons with the brand name Crayola, a word coined by Alice Stead Binney, Edwin Binney’s wife. Crayola initially offered 18 crayon boxes of different sizes, as well as five different sizes of crayon. Initially, Binney & Smith marketed its crayons to artists. Ironically, Edwin Binney was colorblind.

In 1904, the company won another St. Louis World’s Fair gold medal, this time for crayons. As a result, the company added a gold medal to its packaging. In 1926, Binney & Smith acquired 22 new crayon colors when it acquired Munsell Color Company, which also made crayons. In 1939, Crayola combined all its crayon colors into a 52-pack of assorted crayons.

In 1958, Crayola offered a 64-color box of crayons. It contained a built-in crayon sharpener, an innovation that made the product wildly popular. In 1963, the company went public and began trading on the American Stock Exchange. Binney & Smith acquired the rights to Silly Putty, a stretchy, clay-like substance marketed for its malleability and bounce. Hallmark Cards acquired Binney & Smith in 1984. Three years later, the company added colored pencils and washable markers to its product line. In 2007, Hallmark transformed Binney & Smith into Crayola LLC.

Today, the former Binney & Smith operates production, marketing, and sales facilities in the United States, Canada, England, Germany, Australia, Italy, and Germany. In addition to crayons, colored pencils, and markers, the company produces the brands Silly Putty, Magic Marker, Liquitex, and Revell-Monogram (producer of fine scale models).

Peg A. Lamphier

See also Vol. 2, Sec. 1: Crayons; Office Technology (Pre–World War II)

Further Reading

Slater, Lee. 2016. *Crayola Creators: Edwin Binney and C. Harold Smith*. n.p.: Checkerboard.

Birdseye, Clarence (1886–1956)

Inventor and businessman Clarence F. Birdseye was America’s preeminent innovator in the frozen-food industry. Birdseye discovered how to flash freeze food so that ice crystal formation caused minimal damage, creating frozen food, particularly vegetables, that more closely approximated fresh food.

Born to Ada Jane Underwood and Clarence Frank Birdseye in 1886, Birdseye was the sixth of the family’s nine children. He attended Amherst College for two years but was unable to afford the tuition to finish his degree. He dropped out of college and took a job at the U.S. Agriculture Department. He worked in New Mexico and Arizona as an assistant naturalist, supplementing his wages by trapping coyotes and selling their fur.

He also worked for noted Rocky Mountain spotted fever researcher Willard King, capturing thousands of ticks for use in King’s Hamilton, Montana, lab. In 1912, Birdseye took a job in Labrador, Newfoundland, Canada, as a fur trapper. There he had contact with local Inuit people. From these indigenous people, he learned to ice fish and observed that in below-zero weather, the fish he caught froze very quickly and, when thawed, looked and tasted like fresh fish.

He suspected that his observations of frozen fish might prove an entrepreneurial opportunity. He also thought he might be able to freeze other kinds of food, including vegetables, this way. At the time, food was generally frozen at temperatures that allowed the development of large ice crystals, which broke cell walls and caused the food to be mushy and unappetizing when thawed.

By 1922, Birdseye was conducting freezing experiments for the Clothel Refrigeration Company. Two years later, he founded Birdseye Seafood to sell flash frozen fish filets. Consumers, cognizant of the typically low quality of frozen fish, wouldn’t buy his, and the company went bankrupt. Birdseye answered this failure by developing a new method

for freezing fish, packing the filets in cartons and freezing the packages under low temperature and high pressure. This fish product proved saleable, and Birdseye's second company, General Seafood Corporation, was born.

Birdseye patented his freezing method and moved his company to Massachusetts in 1925. He also innovated machinery for his packing plant that he also patented. Four years later, he sold his company to the company that would become General Foods Corporation for \$22 million. That company developed Birds Eye frozen foods and continues to be a leader in frozen food production. Clarence Birdseye continued to work for his former company, innovating new methods for freezing food.

Over the course of Birdseye's life, he patented over 300 inventions, including a process for dehydrating food. He also pioneered the practice of leasing freezer cases to grocery store owners who could not otherwise afford the expensive machinery. Birdseye died in 1956. Today, his name is synonymous with quality frozen food.

Emma E. L. Burke

See also Rocky Mountain Laboratories; *Vol. 2, Sec. 1: Food Preservation*

Further Reading

Kurlansky, Mark. 2013. *Birdseye: The Adventures of a Curious Man*. New York: Doubleday.

Blender

The blender is an electric appliance that has a tall container with a small blade at the bottom of it powered by a small motor in the base. It is used for chopping, grinding, and pureeing food.

The first blender was invented in 1922 by Stephen J. Poplawski and was meant for making malts and milkshakes. In 1932, Poplawski received patents for a blender that would liquefy fruits and vegetables. In 1933, Fred Osius improved Poplawski's blender and received financing and promotion for the blender from Fred Waring, the popular musician. This blender, named the "Miracle Mixer," displayed several

technical problems, which prompted Waring to dump Osius and redesign the blender.

In 1937, Waring introduced the Waring Blender and marketed it to hotels, restaurants, and later to upscale stores such as Bloomingdale's. Waring predicted that his blender would "revolutionize American drinks," which it did. The blender is known for the preparation of cocktail drinks; however, it also became an important tool in laboratories and hospitals. Dr. Jonas Salk used the blender in his development of the polio vaccine. In 1949, Vitamix advertised "The Blender" in one of the first television infomercials.

Emma E. L. Burke

See also Gumball Machine; Pop-Up Toaster; *Vol. 2, Sec. 1: Can Opener; Carpet Sweeper; Curling Iron; Dishwashing Machine*

Further Reading

Alexander, Brian. 2004. *Atomic Kitchen: Gadgets and Inventions for Yesterday's Cook*. Portland, OR: Collectors Press.

Blodgett, Katherine (1898–1979)

Katherine Blodgett was the first woman to be awarded a doctorate in physics from the University of Cambridge. Her career at General Electric would span decades and led to the invention of "invisible glass." She also worked on improvements in glass manufacture and use in a variety of industries.

Born in 1898, Katherine grew up in Schenectady, New York—the home of the General Electric Laboratory. After her father was murdered, Blodgett spent much of her childhood in France. In 1912, she returned to New York to attend Rayson School, where her talent for mathematics and physics became evident. She attended Bryn Mawr College and later obtained her master's degree from the University of Chicago. In 1921, while at work on her masters, Blodgett published a paper describing the use of carbon filters in gas masks.

In 1926, Blodgett became the first woman to be awarded a PhD in physics from the University of Cambridge. Her work gained her the attention of

General Electric, where she was hired as the first female scientist to work for the General Electric Laboratory in Schenectady. Working in the lab under Irving Langmuir, she devised a method to spread monomolecular coatings one at a time onto glass or metal; they were later applied with a device known as the Langmuir-Blodgett trough. Her technique enabled the laboratory to produce glass that had more than 99 percent transmissivity: the first “invisible” glass through which over 99 percent of light could pass. Blodgett’s type of nonreflective coating is now known as Langmuir-Blodgett film and is widely used in cinema lens and eyeglass manufacturing. The first major cinematic production to use invisible glass was *Gone with the Wind* (1939), which was noted by critics for its crystal-clear cinematography. Langmuir-Blodgett film was also used for submarine periscopes and airplane spy cameras during World War II.

Blodgett remained with General Electric for the rest of her professional life. Throughout her career, she created numerous inventions, including the color gauge, a method to measure the molecular coatings on glass to one-millionth of an inch; poison gas absorbers; methods of deicing aircraft wings; and improvements to smokescreens used in military battles. Blodgett was issued eight patents during her career; for six of these, she was listed as sole inventor. She published over 30 papers in scientific journals, and her studies in electrical discharges laid the foundations for plasma physics.

The recipient of numerous awards, Blodgett became the first industrial scientist to receive the Francis Garvan Medal in 1951. She never married, instead living with female partners—first, Gertrude Brown, and later, Elsie Errington—in Schenectady. Blodgett was also actively involved in her community, participating in theater and civic life while pursuing interests in gardening, astronomy, antique collecting, and poetry. She died in her home in 1979.

Tiffany Rhoades

See also Bryant, Alice; Noether, Amalie Emmy; *Vol. 2, Sec. 1*: Knight, Margaret; Kinematoscope; Roebling, Emily; *Vol. 2, Sec. 3*: Clarke, Edith; Wu, Chien-Shiung



Physicist Katherine Barr Blodgett, who invented invisible antiglare glass in 1938, became the first woman to receive a PhD in physics from Cambridge University. (Alfred Eisenstaedt/Pix Inc./The LIFE Picture Collection/Getty Images)

Further Reading

Rayner-Canham, Marelene F. 1998. *Women in Chemistry: Their Changing Roles from Alchemical Times to the Mid-Twentieth Century*. Washington, D.C.: American Chemical Society.

Boeing, William E. (1881–1956)

William E. Boeing is best known for founding one of the earliest American corporations dedicated to designing, manufacturing, and selling airplanes; it eventually became a worldwide concern.

Boeing was born in 1881 in Detroit, Michigan. He attended Yale University for three years and then left without graduating in 1902 to start a lumber business in the Pacific Northwest. Around 1905, Boeing became interested in aviation, and in 1915, he learned to fly in

Los Angeles. In 1909, during an expedition in Seattle, Boeing saw a manned airplane for the first time. To pursue his interest in aviation, Boeing started off by buying a shipyard in Seattle and turned it into Pacific Aero Products Company, the first airplane factory, in 1916. His business partner, George C. Westervelt, served as a lieutenant in the U.S. Navy.

Boeing's first venture started with a small group that was working out of a combined factory and hangar space, and Pacific Aero Products earned a military contract for building ships. However, armistice was reached, so the contract was canceled. Due to the canceled contract, Pacific Aero Products faced difficult financial times; the partners were left with a lack of work. To increase revenue and escape bankruptcy, the company began experimenting, leading to the creation of a "flying boat." Originally known as the B-1, it was used to carry mail for several years between Seattle and Vancouver, British Columbia, Canada. Boeing earned one of the first international airmail contracts in 1920 for shuttling mail with the B-1 flying boat.

In 1919, Boeing completed the B&W Model 1, a single engine, two winged sea plane. Boeing offered the plane to the navy, which declined its purchase. In 1917, Boeing renamed his company Boeing Airplane Company to better represent its focus on airplanes. In 1920, the company was able to secure a manufacturing contract to build 200 Thomas-Morse MB-3 fighter planes. And in 1923, Boeing debuted the Model 40, which allowed Boeing to enter the airmail industry successfully.

During the 1920s, Boeing's Model 40, a single-engine biplane, was widely used by airmail services in the United States. In 1925, the federal Kelly Act opened airmail contracts to private companies, and in a swift move, Boeing won a contract with the redesigned Model 40A, which had air-cooled engines rather than the traditional water-cooled type. The contract required Boeing to prepare 26 airplanes by July 1, 1927, so Boeing provided a \$500,000 bond of his own personal money to expedite production. The Model 40A could not only carry mail, but also two passengers in its enclosed cabin. In 1927, to meet a government regulation, Boeing created the Boeing Air Transport (BAT), a company that transported both passengers and mail.

The Boeing Air Transport, in its first year in service, carried over 800,000 pounds of mail across the country, including 150,000 pounds of express packages. The BAT also carried nearly 2,000 passengers that year. Boeing continued to add more passenger capacity, especially through improving engines. In 1929, Boeing created the first biplane that was specifically meant only for passengers. At its debut, the Model 80 boarded 12 passengers with ease. The upgraded Model 80A could board 18 passengers on a single flight.

Prior to 1927, passengers had hardly any interest in crossing international waters in a plane until Charles A. Lindbergh crossed the Atlantic that year. Data show that in 1926, only 5,800 passengers flew, but a few years later, the number had grown to more than 400,000. This spike of interest in flying greatly benefited Boeing and allowed it to create and improve more planes. It began to assemble an industrial empire.

To improve Boeing's grasp on the aviation industry, Pacific Air Transport merged with Boeing Airplane Company and Boeing Air Transport, and the resulting firm was called United Aircraft and Transport Corporation. It offered a variety of services including civil and military aviation—particularly cargo, passenger, private, and airmail transportation.

Bryan Villafuerte

See also Airplane; *Vol. 2, Sec. 1*: Wright, Wilbur and Orville; *Vol. 2, Sec. 3*: Curtiss-Wright Aeronautical Engineering Cadettes

Further Reading

- Banham, Russ. 2015. *Higher: 100 Years of Boeing*. San Francisco: Chronicle Books.
- Ferry, Steven. 2000. *The Story of Boeing*. Mankato, MN: Smart Apple Media.
- Wallick, Rebecca. 2014. *Growing Up Boeing: The Early Jet Age through the Eyes of a Test Pilot's Daughter*. Lynnwood, WA: Maian Meadows.

Bottle-Making Machine

While glass bottles date back to 100 BC, they were not widely used until the process for their manufacture was automated. In 1904, Michael Owens invented the

automatic bottle-making machine, revolutionizing the container industry.

In the 1880s, a number of companies produced bottles, most with the help of glassblowing machines. The process, which relied on skilled workers, was slow, and thus the bottles were relatively expensive. In 1888, Michael Owens took a job with the Toledo Glass Factory owned by Edward Libbey. In time, Owens became the plant supervisor, all the while working on a machine that would automate bottle making. In 1903, he founded Owens Bottle Machine Company and the next year patented an automatic bottle-making machine. In his lifetime, he would patent five bottle-making or glass-shaping machines. In 1919, he partnered with Libbey to form the Owens-Illinois Glass Company, a company still manufacturing glass products today. Owens died in 1923.

The automated bottle-making machine revolutionized the soft drink and beer industries. Now with an affordable way to bottle beverages, companies inundated American consumers with a wide variety of them. Coca-Cola's iconic "hobble-skirt" bottles, for example, were a product of automated bottle making.

Emma E. L. Burke

See also *Vol. 2, Sec. 1: Coca-Cola*

Further Reading

Pendergrast, Mark. 2013. *For God, Country and Coca-Cola: The Definitive History of the Great American Soft Drink and the Company That Makes It*. New York: Basic Books.

Bread Slicer and Wrapping Machine

A bread slicer and wrapping machine is a machine that slices and packages loaves of bread. After the bread is sliced, it travels to a packing machine. Iowan Otto Frederick Rohwedder invented the bread slicer. The world's first mechanically sliced bread went on sale July 7, 1928.

Otto Rohwedder took his machine to a struggling baker named Frank Bench in his hometown, Davenport, Iowa. After Rohwedder showed Bench how the machine worked, Bench used the machine in his bakery. Just two

weeks later, his sales had increased by 2,000 percent. Bench's customers loved the convenience of presliced bread. It was not long until more bakeries wanted Rohwedder's bread-slicing machines. Rohwedder's company, Mac-Rho, could scarcely keep up with demand. Thus began the bread-slicer-and-wrapping-machine industry, which would give rise to companies like AMF and Oliver Packing and Equipment.

Today there are many different models of bread slicer and wrapping machines, including the Saber 60 Band Slicer, Saber 75 Wide Band Slicer, Mark 60 Bread Bagger, and the Combo Bread Slicer and Bagger. AMF uses Saber Slicers and Mark Baggers because their maintenance is quick and efficient. Mark Baggers are equipped with an automated pendulum scoop drive that eliminates the cost of maintaining gearboxes that use high-friction slide action. Electronic synchronization with the bread slicer can eliminate high-maintenance chain or shaft drives. Saber Slicers have a heavy-duty stainless-steel lattice and blade guidance system for good slice quality.

Oliver Packing and Equipment Company, based in Grand Rapids, Michigan, has been manufacturing bread slicers since 1932. It is said that there are over 20,000 Oliver bread slicers that operate in North America alone. The Oliver Packing and Equipment Company has many different bread slicers, including the 2005 Compact Variable Bread Slicer, the Front Load Slicer 732, the Gravity Feed Bread Slicer 797, and many others.

Twenty-first-century consumers take sliced bread for granted, but until Rohwedder invented a bread-slicing machine, they had to slice their own bread. Mass production bread slicing creates uniform slices, and we now find it difficult to imagine bread appearing any other way. The bread-slicing machine is one of those inventions that is so integrated into American life that it is essentially invisible.

Alicia L. Garcia

See also Pop-Up Toaster; *Vol. 1, Sec. 1: Franklin Stove; Vol. 1, Sec. 3: Papermaking Machine*

Further Reading

Martin, Jim. 2007. *Sliced Bread: . . . the History & Humor of Route Sales*. Bloomington, IN: AuthorHouse.

Bryant, Alice (1862–1942)

Alice Bryant was the first female surgeon to specialize in otolaryngology, a specialty in ear, nose, and throat structures. She invented and developed a variety of medical and surgical equipment for her specialty. Bryant also published more than 75 articles in her field and created evening clinics at Boston's Trinity Dispensary for those who worked during the day. In June 1914, Bryant was one of only two women among thousands of applicants who were admitted to the American College of Surgeons (ACS).

Alice Bryant was born in 1862. Bryant attended the Massachusetts Institute of Technology from 1882 through 1883, and then in 1885, she received her bachelor's degree from Vassar College. She got her medical degree in 1890 from the Women's Medical College of New York. After being accepted by the American College of Surgeons in 1914, Bryant worked at the New England Hospital for Women and Children and New England Deaconess Hospital as a medical practitioner. Bryant developed evening clinics at the Boston Trinity Dispensary for her patients' convenience so that those who worked during the day could seek out medical treatment after work had ended. This made her known for flexible hours.

Bryant developed a number of medical instruments that are used today; they became standard in the field. She developed a new tonsil tenaculum and a nasal polyp hook, which are used in tonsillectomies and the removal of nasal polyps; she also designed tonsil separators, bone-gripping forceps, and a tonsil snare cannula. The tonsil separator is a tool that has a short, beveled blade and is used to cut through the plica and mucous membrane, assisting in removing a tonsil from the surrounding tissue. The bone-gripping forceps is a clamp is used on the bone to apply compressive force during surgical procedures. One of the 75 articles that Bryant published was "The Use of the Cold Wire Snare in the Removal of Hypertrophied Tonsils," which was published by the *British Medical Journal* in November 1906.

Bryant was also part of many scientific and humanitarian organizations. In 1921, she was a member of the American Society of Heating and Ventilating Engineers, which conducted lab studies on air. Bryant, along with other doctors, joined with air-

conditioning engineers who studied the combination of air motion, humidity, and temperature to find what most people preferred. In 1924, Bryant gave a lecture on educating the hard of hearing about the value of voice training and lip reading. Bryant worked until she became sick and died on July 25, 1942.

Sjoen Koepke

See also Noether, Amalie Emmy; *Vol. 2, Sec. 3*: Clarke, Edith; Lamarr, Hedy; *Vol. 3, Sec. 1*: McClintock, Barbara

Further Reading

Braun, Sandra. 2007. *Incredible Women Inventors: Women's Hall of Fame Series*. Toronto: Second Story Press.

Latta, Susan. 2017. *Bold Women of Medicine: 21 Stories Astounding Discoveries, Daring Surgeries and Healing Breakthroughs*. Chicago: Chicago Review Press.

Cannon, Annie Jump (1863–1941)

Nicknamed the "Census Taker of the Sky," Annie Jump Cannon developed the Harvard Classification Scheme in collaboration with Edward Pickering. Cannon's classification was the first to organize stars by their temperatures and spectral types, and she used it to classify more stars than any other person.

Born to Mary Jump Cannon and Wilson Cannon in 1863 in Dover, Delaware, Annie evinced an early interest in the stars. She and her mother identified stars together, observing the skies from the attic of their home. She attended Wellesley College, where she contracted scarlet fever. The disease left her partially deaf for the rest of her life, a condition that may have made socialization difficult, resulting in her immersing herself in her work. In 1884, she graduated as valedictorian with a degree in physics. She took care of her sick mother for the next 10 years, and then she returned to Wellesley to take graduate courses. She studied astronomy, spectroscopy, and photography before enrolling in Radcliffe Women's College, then the women's arm of Harvard College. Because of her age and hearing disability, she attended as a "special student" and did not earn a degree.

In 1896, Cannon joined Edward Pickering's staff of female mathematicians known as the Harvard Computers (and sometimes as "Pickering's Harem"). The lady "computers" undertook the mathematical calculations to transform astronomical observational data into material that could be entered into the Henry Draper Catalogue. Before long, Cannon was analyzing thousands of stars in order to classify them by their light spectra. She developed the now-famous OBAF-GKM classification system based on the strength of the Balmer absorption lines known to represent stellar temperatures.

At the Harvard College Observatory, as a member of the Harvard Computers, Cannon took over the work of her predecessors Nettie Farrar, Williamina Fleming, and Antonio Maury in analyzing thousands of stars. Cannon applied her own scheme to the data, developing the OBAFGKM (Oh, Be A Fine Girl, Kiss Me) classification system and the mnemonic device that has helped decades of students remember it. Cannon first published her star-cataloging system in 1901. In 1922, the system had become so accepted that the International Astronomical Union resolved to adopt it as its official star classification system.

In 1907, Cannon earned her master's degree. She continued to work with the Harvard College Observatory and went on to classify more stars than any other astronomer in history—around 350,000. She could classify three stars per minute by looking at their spectral patterns, and, using a magnifying lens, she could classify stars down to the ninth magnitude—around 16 times fainter than the human eye can see. Her findings were published in the Draper Catalogue. Cannon also discovered 300 variable stars, five novae, and one spectroscopic binary.

In 1925, Cannon earned the first honorary doctorate from Oxford University to be awarded to a woman. She also received honorary doctorates from Groningen and Oglethorpe Universities. She became the first female officer of the American Astronomical Society and the first woman to win a Henry Draper Medal (1931) for achievements in astronomy. In 1933, she attended the Chicago World's Fair as a representative of American professional women.

In 1938, Cannon was appointed to the faculty at Harvard College and named the William C. Bond



Annie Jump Cannon was the first astronomer to catalog the stars systematically, and she also discovered 277 long-period variable stars and five novae. She was the most famous female astronomer of the first half of the 20th century. (Library of Congress)

Professor of Astronomy. Although she officially retired in 1940, after more than 40 years as an astronomer, she continued to do research at the observatory.

Annie Jump Cannon died in 1941 in Cambridge, Massachusetts. Like Maria Mitchell, a mid-19th century astronomer, Cannon's achievements and contributions to professional astronomy have been largely forgotten by the American public. Nonetheless, she and Mitchell must be counted among America's greatest astronomers of any gender.

Peg A. Lamphier

See also Vol. 2, Sec. 1: Harvard Computers

Further Reading

Greenstein, George. 1993. "The Ladies of Observatory Hill: Annie Jump Cannon and Cecilia Payne-Gaposchkin." *The American Scholar* 62, no. 3 (Summer): 437–46.

Carothers, Wallace (1896–1937)

Wallace Carothers was an inventor, chemist, and leader of organic chemistry at DuPont. Carothers developed nylon and synthetic silk, helped invent neoprene (a synthetic rubber), and derived the Carothers equation, which relates the degree of polymerization to the fractional monomer conversion. He received his PhD from the University of Illinois and received the Carr Fellowship, the most prestigious award for that university at that time for the 1923–1924 academic year. Carothers committed suicide after struggling with depression.

Carothers was born in Burlington, Iowa, on April 27, 1896. He was the oldest of four children. In his youth, he developed an interest in tools and mechanical devices. Carothers attended Tarkio College, located in Missouri, after being pressured by his father to do so. He majored in English before switching to chemistry. Carothers became a chemistry instructor before he graduated. In 1920, Carothers graduated from Tarkio College and attended the University of Illinois, where he gained his master of arts degree in 1921.

Carothers was a chemistry instructor from 1921 to 1922 at the University of South Dakota. Here he began doing independent research, which was accepted and published by the *Journal of the American Chemical Society*. Carothers's research measured the physical properties of phenyl isocyanate and of diazo benzene; he discovered that the structure of the latter compound was a chain rather than a ring.

Carothers returned to the University of Illinois, where in 1924 he received his PhD. Here he minored in mathematics and physical chemistry, specializing in organic chemistry. Carothers taught at the University of Illinois for two years in organic chemistry, and then in 1926, he moved to Harvard University, where he was an instructor of organic chemistry. In 1927, Carothers worked at DuPont's experimental station, where he researched the synthesis of polymers. Here he helped create neoprene, synthetic silk, an elastic synthetic fiber, polyamide, and last, nylon.

In 1934, Carothers drove to Baltimore to consult a psychiatrist, who enrolled him in a clinic for depression. In 1936, Carothers married Helen Sweetman. Carothers was elected to the National Academy of Science later

that year in April. By June, Carothers had been admitted to the Institute of the Pennsylvania Hospital for depression, which he had struggled with since his childhood. Eventually, Helen agreed with Carothers's doctor that she was not able to care for Carothers. His sister died of pneumonia in 1937, and later that year, Carothers committed suicide by ingesting cyanide dissolved in lemon juice—which is known to accelerate the effects of the poison. In 1982, Carothers was posthumously inducted into the Alpha Chi Sigma Hall of Fame, a professional fraternity that specializes in chemistry.

Sjoen Koepke

See also *Vol. 2, Sec. 3:* Neoprene; *Vol. 3, Sec. 1:* Bulletproof Vest/Kevlar

Further Reading

Hermes, M. E. 1996. *Enough for One Lifetime: Wallace Carothers, Inventor of Nylon (History of Modern Chemical Sciences)*. Philadelphia: Chemical Heritage Foundation.

Mark, H. 1940. *Collected Papers of Wallace Hume Carothers*. New York: Interscience.

Christmas Tree Lights

For centuries, families brought life to their Christmas trees by lighting candles placed on them. Though the sight was rather pleasant, it proved to be a hazard, as many of the trees would catch on fire and cause damage to homes as well as deaths. In the late 1800s, Edward H. Johnson introduced a much safer alternative with his creation of electric Christmas tree lights. With this goal in mind, he hired Thomas Edison and eventually worked for the Edison Electric Light Company under the title of vice president. He was also the chief engineer for a system previously introduced by Edison himself.

In 1882, the public witnessed Johnson's creation. He had strung together 80 small multicolored lightbulbs to be powered simultaneously through a single cord. This proved not only much more visually pleasing than candles but much safer. As much of an improvement that it was, it still had its detriments. At the time, electricity was still foreign to the public, so Christmas lights were considered a luxury. The cost of an electrician to

wire the bulbs properly and have them all working steadily was fairly expensive—as much as \$300, about the equivalent of \$6,700 today. To address this issue, General Electric, a company founded by Edison and others in 1892, provided lights assembled as kits.

Electric Christmas tree lights gained a publicity advantage when the first electrically lit Christmas tree appeared in the White House during the administration of President Grover Cleveland in 1895. Yet, Christmas lights would not be readily available to the general public until the late 1910s. The idea of selling the lights was that of Albert Sadacca, whose family already owned a lighting company. Later innovations included blinking lights, bubble lights, icicle lights, and eventually light-emitting diode (LED) lights, which promised to save energy.

Edward H. Johnson's innovative idea of Christmas tree lights saved many lives that could have been lost if he had not had it. His idea has become a tradition that is still used over 100 years later.

Dannela Azul Valencia

See also *Vol. 2, Sec. 1*: Edison, Thomas; General Electric; *Vol. 3, Sec. 1*: LED Lights

Further Reading

Klein, Christopher. 2014. "The Father of Electric Christmas Tree Lights." *History*. December 19. <http://www.history.com/news/the-father-of-electric-christmas-tree-lights>, accessed August 29, 2018.

Long, Tony. 2008. "Dec. 22, 1882: Looking at Christmas in a New Light." *Wired*. December. <https://www.wired.com/2008/12/dec-22-1882-looking-at-christmas-in-a-new-light-2>, accessed August 29, 2018.

"Who Invented Electric Christmas Lights?" *Everyday Mysteries: Fun Science Facts from the Library of Congress*. <https://www.loc.gov/rr/scitech/mysteries/christmaslights.html>, accessed August 29, 2018.

Chuck Wagon

The chuck wagon was a 19th-century canvas-covered wooden wagon purposed as a mobile kitchen and invented by Charles Goodnight (1836–1929). This

precursor to modern-day catering or food trucks serviced cowboys on cattle drives across 20th-century America. Considered the most successful rancher in the early American West, Goodnight was a consummate cattleman, a Texas Ranger, pioneering cattle breeder, and designer of the first chuck wagon. At the height of his success with business partner and experienced cattleman Oliver Loving (1812–1867), their Texas million-acre cattle ranch contained over 100,000 head. The impact of the chuck wagon enabled cowboys to exist longer on the trail, far from any towns. This fueled the demand for beef and enabled the expansion of the beef industry for over two decades.

During the American Civil War (1861–1865), Texas Longhorn cattle, abandoned by owners who joined the war effort, multiplied in huge numbers—by some claims, between 3.5 and 6 million heads. Upon the end of the war, these massive herds were rounded up by "cow hunters" and claimed by enterprising ranchers. This signaled the first beginnings of the great American cattle trail drives. Those cattle not already with brands were branded with the heated iron stamp of their new owners and were spurred on by cowboys across the plains to military installations, Indian reservations, or sold, to begin a new life on a ranch or to be herded onto a train bound for the slaughterhouse. Goodnight realized that such an enormous undertaking required an equal amount of human labor able to withstand the rigors of long-distance travel over difficult terrain. An efficient system was needed to sustain this labor force, often for months at a time.

Designed in the late 1860s to early 1870s out of a Civil War surplus medical wagon, Goodnight's retooling of a wagon for wartime use to a post-wartime meal wagon sufficient to feed hungry cowboys was an innovative idea for the era. Before Goodnight's novel use of the medical wagon, cowboys carried their bedrolls under their saddles and their rations, which consisted of pork, coffee beans, salt, and sometimes cornbread, in a hand-sewn pouch attached to their saddles. With Goodnight's invention, cowboy cattle drivers were afforded a meal, a place to store personal items, rifles, and bedrolls without adding burden to their horses.

The origin of the term "chuck wagon" is likely Goodnight's repurposing of the wagon's "mess box,"

also known as a “chuck box.” The box, which fitted inside the back of the wagon, was designed with stacked drawers that acted as a larder for food and storage for cooking utensils. This mobile pantry might include dried beans, flour, and coffee along with first-aid supplies, cutlery, plates, and cups. Cast-iron pans and a Dutch oven, plus a round, cast-iron pot on three legs with a matching lid, rounded out the portable kitchen’s inventory. The typical layout of the chuck wagon included barrels of water attached to the outside, along with a toolbox and a coffee grinder. At the rear of the wagon, the chuck box sat enclosed behind a hinged, drop-down cover made of wood, which served the dual purpose of cooktop counter, propped up by a single leg.

The chuck wagon, pulled along by a team of oxen driven by a cook or Teamster, enabled cattle drives to self-sustain for long distances. When out on the plains far from home, the chuck wagon and the cook served as the social center for the life of the cowboy. Along with the business of planning, cooking, and baking meals, manners would be enforced and wounds tended to by the cook, who took on whatever contributed to a certain stability in an often harsh environment on the open trail. This cowboy protocol as dictated by the cook offered some semblance of home life: a hot meal, conversation, and a place to stow personal belongings.

Life on the open range lasted until before the turn of the 20th century. The open range herding of cattle faded as western migration continued, resulting in smaller, localized ranches and the increased use of barbed-wire fencing. With that, the purpose of the chuck wagon faded as well.

Cynthia J. Parker

See also *Vol. 1, Sec. 3: Conestoga Wagon*

Further Reading

- Manns, William, and Elizabeth Clair Flood. 1997. *Cowboys & the Trappings of the Old West*. Santa Fe, NM: Zon International.
- Nelson, Doug. 1993. *Hot Cakes to High Stakes: The Chuckwagon Story*. Calgary, Alberta: Detselig.
- Williams, Jacqueline. 1993. *Wagon Wheel Kitchens*. Lawrence: University Press of Kansas.

de Forest, Lee (1873–1961)

Lee de Forest, the “Father of Radio,” was an inventor who dedicated himself to media technology. Best known for his Audion, a three-element amplifying vacuum tube, de Forest was also responsible for Phonofilm, which added sound to motion pictures. De Forest held more than 180 patents, although many of his inventions were small improvements on existing technology.

De Forest was born in Council Bluffs, Iowa, to Henry Swift de Forest, a Congregational minister, and Anna Margaret Robbins. The family moved to Alabama, and de Forest was sent to the Mount Hermon School for Boys in Massachusetts. In 1893, he entered Yale University’s Sheffield Scientific School on a family scholarship and graduated with a PhD in 1899.

After graduation, de Forest worked for the Western Electric Company in Chicago on dynamos and telephone equipment. He also did experimental work in wireless telegraphy on the propagation of electromagnetic waves.

In 1902, de Forest and promoter Abraham “Abe” White formed the American DeForest Wireless Telegraph Company, with de Forest acting as the company’s scientific director. White promoted the company heavily, including building a tower at the 1904 Louisiana Purchase Exposition in St. Louis, Missouri, and operating 10 broadcast stations at the fair. However, the company ran into legal issues with stock fraud, and in November 1906 de Forest resigned.

That same month, de Forest received a patent for a two-electrode tube based on an earlier valve-like tube created by British electronics pioneer J. A. Fleming (1849–1945). Both tubes relied on something called the “Edison effect,” where electrons were observed to flow from a heated element to a cool one. Tinkering with the design, de Forest added a third wire, or grid, and named his invention the Audion. He received a patent for it in 1908 and in 1912 sold the rights to the American Telephone and Telegraph Company for use in long-distance telephony. The Audion would become a staple in radio transmission and reception.

On July 18, 1907, de Forest’s new company, the De Forest Radio Telephone Company, sent the first ship-to-shore radio broadcast. But the equipment

proved unreliable, and in 1912, the company collapsed. De Forest was prosecuted for mail fraud.

In 1920, de Forest worked with physicist Theodore Case (1888–1944) to develop a system of recording sound directly onto film. Although the system was a success, buyers were not interested, and the De Forest Phonofilm Corporation, established in 1922, shut its doors in 1926.

De Forest was elected president of the Institute of Radio Engineers in 1930. For the next 20 years, he promoted shortwave radio, despite opposing the commercialization of radio. He was bitter about his business failures and felt he had been cheated of fame and fortune. De Forest died on July 1, 1961, from a heart attack.

Karen S. Garvin

See also Radio; Talking Movies; Triode Tube

Further Reading

Adams, Mike. 2012. *Lee de Forest: King of Radio, Television, and Film*. New York: Copernicus Books.

Douglas, Susan J. 1987. *Inventing American Broadcasting, 1899–1922*. Baltimore: Johns Hopkins University Press.

Eyman, Scott. 1997. *The Speed of Sound: Hollywood and the Talkie Revolution, 1926–1930*. New York: Simon & Schuster.

Dickelman, Elizabeth (dates unknown)

Elizabeth Hetzel Dickelman, better known as Lizzie, made a number of contributions to the agricultural field with her inventions and patents. Dickelman and her husband, Joseph L. Dickelman, were both a huge part of the agricultural world with her patents and their company, the Dickelman Manufacturing Co. Some of the patents under her name are for metal building plate, grain storage construction, the elastic corncrib, a grain storage bin, a ventilated grain storehouse, and the brooder house. With these patents to her name, she and her husband are considered pioneers in the agriculture field. Although many of her patents and inventions were great advancements for those in agriculture, a couple of them stand far above the rest: the corncrib and the brooder house.

A corncrib is a storage facility used in agriculture to dry and store corn; it is typically made from wood to facilitate airflow. Corncribs resemble small buildings or sheds placed high above the ground to prevent flooding and easy access for animals. Most corncribs have slits or gaps to allow air in so that the corn inside can dry properly.

Once the corn is harvested, it can be placed in a crib with or without husks. Although the principal use for the shelter is to store corn, many other crops can benefit from being placed in a corncrib—such as sunflowers, peas, beans, and tobacco.

One of Dickelman's more notable patents was one for the brooder house, also called a broiler house. It is a small insulated shelter for young animals, typically recently hatched chicks. The brooder provides them with warmth and protection. The chicks are held there until they are about six weeks old. Brooder houses are usually made of wood and are heated either by electricity or oil stoves. Brooder houses are often on the smaller side, but there are also commercial brooder houses that are large, maximizing the number of livestock being raised.

Fredy G. Mena

See also Vol. 1, Sec. 2: Three-Piece Iron Plow; Vol. 1, Sec. 3: Corn Sheller

Further Reading

Kruger, David Delbert. 2017. *J. C. Penney: The Man, the Store, and American Agriculture*. Norman: University of Oklahoma Press.

Roe, Keith E. 1988. *Corncribs: In History, Folklife, and Architecture*. Iowa City: Iowa State Press.

Dickerson, Mary Cynthia (1866–1923)

Mary Cynthia Dickerson was an American herpetologist and the first curator of herpetology at the American Museum of Natural History. Over the course of her lifetime, she described over 20 species of reptiles, served as editor of *The American Museum Journal*, and published numerous well-received books and articles.

Born in Michigan in March 1866, Dickerson spent her early life caring for her three younger brothers and earning money to put herself through school. She

attended the University of Michigan and earned her bachelor of science degree in 1897 from the University of Chicago. Following her studies, she taught high school biology and later became head of zoology and botany at the Rhode Island Normal School. During her tenure, she led students on nature walks and published two books: *Moths and Butterflies* (1901) and *The Frog Book* (1906). Both became popular reference books.

During the 1907–1908 school year, Dickerson served as an instructor at Stanford University, coauthoring three papers with ichthyologist David Starr Jordan to help describe the new species of halfbeak. In November 1908, she joined the American Museum of Natural History as an assistant in the Department of Woods and Forestry. Her duties included creating exhibit hall guides and developing the museum's collections, for which she amassed over 1,068 specimens and 461 species.

Dickerson's work was the catalyst for the creation of the Department of Ichthyology and Herpetology at the American Museum of Natural History, for which she became the sole herpetologist. She also served as the associate editor and then editor of *The American Museum Journal* from 1910 to 1920, overseeing the record of the museum's work, including field explorations, important acquisitions, and exhibition installations.

As curator, Dickerson instituted a tripartite effort to establish a major herpetological department consisting of exhibition work, collection building, and building a library and center for herpetological research. Unable to find time for her own investigations, Dickerson relied on young scholars who could independently conduct fieldwork and collections-based research. She recruited the museum's herpetologists—including Karl Patterson Schmidt, Gladwyn Kingsley Noble, and Charles Lewis Camp—as part of this effort.

Under her direction, the museum's herpetological collections grew to over 50,000 specimens—enough to warrant the creation of an independent Department of Herpetology in 1920. Dickerson served as the department's first curator. She considered exhibition work of equal importance to research, and she developed the concept of herpetological “habitat group” displays that employed a variety of preparation techniques, including wax casting to create lifelike models. She also described over 20 new species of reptiles, including the San Esteban chuckwalla and the Cuban sharp-nosed amphibia, and is commemorated in

the names of four lizard species: *Cnemaspis dickersonae*, *Aspidoscelis tigris dickersonae*, *Holbrookia maculate dickersonae*, and *Crotaphytus dickersonae*. Dickerson also published numerous popular and scientific articles, and she was a member of the American Academy of Arts and Sciences, American Forestry Association, American Ornithologists' Union, and the New York Academy of Sciences.

In the late 1910s, Dickerson began showing signs of mental disturbance, likely the result of stress. She became increasingly erratic and had auditory hallucinations of the Arctic explorer Vilhjalmur Stefansson, with whom she had been in correspondence on behalf of the museum. In November 1920, she was removed from the museum after a medical evaluation and placed in the care of her brother. On December 24, 1920, she was committed to a psychiatric institution on Wards Island, where she remained until her death in 1923.

Under Dickerson's lead, the herpetology section of the American Museum of Natural History had flourished, breaking new ground in the discovery and classification of amphibians and reptiles.

Tiffany Rhoades

See also Bryant, Alice; Cannon, Annie Jump; Gilbreth, Lillian; Pennington, Mary Engle

Further Reading

Wallace, Joseph. 2000. *A Gathering of Wonders*. New York: Farrar, Straus, and Giroux.

Drew, Charles (1904–1950)

Charles Richard Drew, known as the “Father of Blood Banks,” was born on June 3, 1904, in Washington, D.C. In his early life, Drew invented solutions for the storage and processing of blood for transfusions. Later, he managed two of the largest and best-known blood banks during World War II, which still exist to this day.

Drew was born into a middle-class family and was the eldest of five children. He showed great athletic talent during his youth, winning several medals in his elementary years in a variety of sports, including football, basketball, and swimming. Through 1918 and 1922, Drew attended Dunbar High School. He then attended Amherst College on a sports scholarship.

After completing his bachelor's degree in 1926, Drew did not have the funds to enroll in medical college, so he raised funds by working as a biology teacher and coach at Morgan College, presently known as Morgan State University. In 1928, Drew applied to several medical schools and chose to attend McGill University in Montreal, Canada. At McGill, Drew was awarded with a prize in neuroanatomy and recognized as one of the top students. In 1933, he earned degrees both as a doctor of medicine and master of surgery. Drew then did internships at Montreal General Hospital and at the Royal Victoria Hospital, when he worked closely with Dr. John Beattie to examine issues and problems pertaining to blood transfusions.

In 1938, after extensive research, Drew developed a method to preserve blood plasma (blood without cells). By separating plasma from whole blood, it can be preserved for a longer period. This research served as the basis for his doctoral thesis, and he received his degree in 1940. Drew was the first African American to receive a degree from Columbia University.

During this time, World War II was in motion, and Drew was asked to create a special medical effort known as "Blood for Britain" to collect blood to help overseas casualties. In 1941, Drew began another blood bank effort for the American Red Cross intended for U.S. military personnel. However, because of segregation, donated blood could only be used by a person of the same ethnicity as the person from whom it had originated. Due to this racist policy, Drew resigned.

After creating the first two blood banks, Drew became a professor at Howard University for the Department of Surgery, which led him to become the chief surgeon at Freedman's Hospital. Through his final years, Drew continued to be active and highly respected. He died at the age of 45 in 1950 and was continuously honored post his death by many medical colleges and schools for his contributions.

Bryan Villafuerte

See also Vol. 2, Sec. 3: Blood Transfusion

Further Reading

Schraff, Anne E. 2015. *The Life of Dr. Charles Drew: Blood Bank Innovator*. Berkeley Heights, NJ: Enslow.

Ductile Tungsten

The development of ductile tungsten powered the revolution in electrical lighting. William D. Coolidge invented ductile tungsten in 1909.

Tungsten is a metal that provides a powerful heat resistance and has the highest melting point of all metals; therefore it is useful in very high-temperature applications. Tungsten is nonmagnetic. It is also normally very brittle but can be drawn down smaller than any other metal can; and its specific gravity is 70 percent higher than that of lead. Electric lighting innovators in the late 19th century had difficulty finding a material durable enough to function as electrical filament. In 1909, William D. Coolidge developed ductile tungsten by using powdered tungsten to create an ingot of sintered tungsten through a series of hot swagings and drawings through successively smaller dies, and with this process, bendable wire of many diameters could be made.

Ductile tungsten wire is used as an energy-efficient, high-lumen lighting filament. It has properties that contribute to increased luminosity and a long life for lightbulbs. Nearly every conventional lightbulb has a tungsten filament inside it. Tungsten spurred the rapid expansion of incandescent lamps and initiated the science of modern powder metallurgy.

Warod Changpradith

See also Vol. 1, Sec. 2: Gas Tungsten Arc Welding; Vol. 2, Sec. 1: Edison, Thomas; Electric Lightbulb

Further Reading

Coolidge, William D. 1964. *The Development of Ductile Tungsten (Report)*. New York: General Electric Research Laboratory.

Einstein, Albert (1879–1955)

A German-born theoretical physicist best known for his formulation of the special and general theories of relativity, Albert Einstein immigrated to the United States in 1933. His work provided the groundwork for the development of nuclear power and weaponry as well as the foundation for the first branch of modern

physics (the other being quantum mechanics). He won the 1921 Nobel Prize for his work on the photoelectric effect. Einstein is also known for his antiwar philosophy, caution against nuclear proliferation, and for launching the science of cosmology. He is widely regarded as the most influential physicist of the 20th century.

Albert Einstein was born on March 14, 1879, in Ulm, Württemberg, Germany to Hermann Einstein (1847–1902), a former featherbed salesman turned owner of an electrochemical factory, and Pauline Koch (1858–1920), both secular, middle-class Jews. He also had a sister, Maja (1881–1951), born two years after him. Six weeks after his birth, Einstein's family moved to Munich, where he would eventually begin elementary school at the Luitpold Gymnasium. In the late 1880s, Max Talmud, a Polish medical student and friend of the Einstein household, became an informal tutor in mathematics and philosophy to young Einstein. His inspiration to study physics began early in his life. At age five, he first encountered a compass and became fascinated with the invisible force of magnetism. At age 12, he discovered and voraciously read his first book on geometry. It is often cited that he reached a pivotal turning point at age 16, when Talmud introduced him to a series of children's science books, including one volume containing a scene imagining a race alongside the electricity in a telegraph wire. The notion of what a beam of light would look like if one traveled alongside it at the speed of light dominated young Einstein's thinking, and he produced what is considered his first scientific paper, "An Investigation on the State of the Aether in Magnetic Field."

In 1894, Einstein ran away from a Munich boardinghouse where he had been left as his father struggled with business. He felt alienated by the rigid Luitpold school system and feared impending military conscription upon coming of age, but while they were understanding, his parents feared for his prospects as a school dropout and draft dodger. He managed to enroll in the Swiss Polytechnic School in Zurich to train as a teacher in mathematics and physics. It was there that he met his future wife, Mileva Marić (1875–1948), a Serbian physics student. Upon receiving his diploma in 1901, Einstein encountered difficulty in finding teaching positions, as his habit of independent study

caused him to cut classes and alienate the professors whom he asked for letters of recommendation. He became a technical assistant at the Swiss Patent Office and gained Swiss citizenship the same year. He continued his work in theoretical physics during his spare time. He also married Marić against his parents' objections (his father gave his blessing only upon his deathbed) upon securing a steady income. The fate of their only daughter, Liserl, born before the two were married, remains a mystery.

The year 1905, in which Einstein received his doctorate, is widely regarded as his "miracle year." Einstein produced four major papers that would revolutionize physics: one was on the photoelectric effect and a second was on Brownian motion. However, he is best known for his papers on special relativity and his energy content paper that contained the famous $E = mc^2$.

His papers first came to prominence after being recognized by Max Planck, the founder of quantum theory. He began to do lecture circuits and gain increasingly prestigious academic positions. He was appointed *Privatdozent* at the University of Berne in 1908, became an associate professor of theoretical physics at the University of Zurich in 1909, assumed a similar position at the University of Prague, and finally, went to the University of Berlin to serve as director of the Kaiser Wilhelm Institute of Physics from 1913 to 1933.

In 1915, Einstein expanded special relativity to explain gravity, thus formulating his theory of general relativity: that gravity consists of the curvature of the space-time continuum. In 1921, he received the Nobel Prize for his work on the photoelectric effect.

In 1919, Einstein divorced Marić after a five-year estrangement. That same year, he married his cousin, Elsa Löwenthal (1876–1936). Elsa immigrated to the United States with her husband in 1933 and died of heart and kidney failure in 1936.

In 1933, Einstein came to the attention of the German Nationalist Socialist (Nazi) party. When his work was denounced as "Jewish physics," Einstein renounced his German citizenship and immigrated to the United States to join the Institute for Advanced Study at Princeton, New Jersey. During World War II, modifying his pacifist stance, he worked on naval

weapons systems. Einstein continued his association with the Institute for Advanced Study until his death in 1955.

While having no direct involvement with the Manhattan Project, he spurred its formation by citing concerns to President Roosevelt (1882–1945) with Leo Szilard (1898–1964) over Nazi research into atomic warfare in 1939. His mass-energy equivalency equation proved instrumental in designing the first nuclear bombs. Upon the destruction of Hiroshima, Japan, in 1945, Einstein immediately initiated the Emergency Committee of Atomic Scientists to advocate for control of nuclear weapons. While opposing research into thermonuclear warfare, Einstein did address the United Nations in an article in the *Atlantic Monthly*, espousing the idea of nuclear deterrence as a means of achieving peace.

Einstein is also known for his social work, and he joined the National Association for the Advancement of Colored People (NAACP) in the late 1940s. He joined the World Government Movement after World War II and was offered the presidency of the State of Israel, which he declined. After retiring in 1945, Einstein devoted his time and effort to constructing unified field theories that would explain the universe in a single equation. Unfortunately, Einstein largely ignored new bodies of work produced on the emerging physics of quantum mechanics, and his theories reached no applicable conclusions.

Einstein died on April 18, 1955, in Princeton at age 76. In an autopsy, it was discovered that Einstein's inferior parietal lobe, the part of the brain that processes mathematical, logical, and spatial data, was around 15 percent wider than that of the average brain.

Andres Elvira

See also *Vol. 2, Sec. 3: Manhattan Project; Oppenheimer, J. Robert; Vol. 3, Sec. 3: Quantum Science*

Further Reading

Einstein, Albert. 1916. *Relativity: The Special and General Theory*.

Hawking, Steven, and Leonard Mlodinov. 2010. *The Grand Design*. New York: Bantam.

Isaacson, Walter. 2008. *Einstein: His Life and Universe*. New York: Simon & Shuster.

Electric Traffic Light. See Traffic Light, Electric

Electric Washing Machine. See Washing Machine, Electric

Empire State Building

Completed almost 100 years ago, the Empire State Building stands out as a recognizable icon of New York City. The building was constructed in a city as unique as it is.

Buildings erected in the 19th century relied on load-bearing construction. The taller the building, the thicker the walls needed for support. Most buildings were no higher than six stories tall. Cities in the late 19th century saw their populations grow as more immigrants and others came to them seeking jobs. Cities with limited land, which were unable to build out, looked to build up.

Instead of building thick walls for support, James Bogardus, an iron manufacturer, built a metal frame to carry the weight of a building. Its walls, floors, and windows would rely on the cast-iron frame for support. The metal frame meant that buildings could be built safely and taller: to 16 stories.

Henry Bessemer invented a process that removed impurities from steel that produced steel that was five times stronger than iron. Steel was successfully used to construct the Brooklyn Bridge, completed in 1883.

Taller buildings, however, needed something other than stairs so people could get to the top floors. Elevators had long been used for moving freight, but the cables broke so often that they weren't safe enough to transport people. Elisha Graves Otis invented a braking system so that if its cable broke, an elevator would stop and not crash to the ground.

Tall buildings called “skyscrapers” became more common as safety measures and construction techniques improved. There were 20 buildings over 20 stories tall in New York City by 1929. The Chrysler Building was 61 stories tall. Everyone wanted to build the tallest building.



Smog obscures the view of the Chrysler Building from the Empire State Building, New York City, 1953. The American Society of Civil Engineers named the Empire State Building one of the Seven Wonders of the Modern World. (Library of Congress)

The architectural firm Shreve, Lamb & Harmon designed a building that would be 102 stories tall. The Empire State Building would be 1,250 feet from sidewalk to rooftop. The metal-frame building would have a spire at the top to serve as an anchor for the newest innovation: travel by dirigible.

The site selected was on 5th Avenue between 33rd and 34th Streets. Buildings at that location were demolished, and construction began with steel columns in concrete bases or piers. Each column weighed 44 tons. Steel beams were attached to the columns to make the frame of the building. Floors were made of concrete. Metal rivets connected the metal pieces of the frame. Brick completed the walls.

The building's exterior was done in a modern design style: Art Deco. It was of pale limestone, aluminum panes, and shiny, nickel strips placed over the brick. Sixty-seven elevators were installed inside the building, and the lobby had marble floors.

Construction lasted from early 1930 until September 1930. Workplace safety was important on such a massive project. Only six workers died on the job.

The spire for anchoring dirigibles was used only once in September 1931. The dirigible captain struggled to keep the ship steady in winds while the crew tried to deliver stacks of newspapers from it to those waiting at the top of the building. The dirigible dock was closed and not used again.

The Empire State Building was the tallest building in the world until 1972. The building was designated a National Historical Landmark in 1986 and now holds the number one spot on America's favorite architecture list.

Linda Briley-Webb

See also Vol. 2, Sec. 1: Brooklyn Bridge; Vol. 2, Sec. 3: Golden Gate Bridge

Further Reading

- Clinton, Patrick. 1987. *The Story of the Empire State Building*. Chicago: Regensteiner.
- Lusted, Marcia Amidon. 2005. *The Empire State Building*. Farmington Hills, MI: Thomson Gale.
- Mann, Elizabeth. 2003. *Empire State Building*. New York: Mikaya Press.

Ford, Henry (1863–1947)

Henry Ford was the founder of Ford Motor Company. From an early age, Ford loved fixing, designing, and working with machines. Although his father wanted him to be a farmer, he devoted much of his time and energy to machines and business ventures. Even though Ford was not the first person to invent automobile technology or the assembly line, he is remembered because he perfected both. His contributions in these areas in the early 1900s helped transform the automobile from a luxury to a necessity. In later years, the automobile evolved into a permanent part of American culture. After Ford's death, his legacy as an important American industrialist, though with human flaws, was secure.

Ford was born in Springwells, Michigan, on July 30, 1863, and raised on a farm. The farm machinery fascinated him, and, due to his tinkering with it, he

became a self-taught machinist. His mother provided him with his early education, and he attended a one-room schoolhouse in the Dearborn school district in Wayne County, Michigan, during his teenage years.

Ford left home at the age of 16 and found work in Detroit, Michigan, as an apprentice for the James Flowers and Brothers Machine Shop. After learning how to manufacture valves and fire hydrants for the growing city, he terminated his apprenticeship after nine months and secured a job working with steam engines at the Detroit Dry Dock Company. From 1844 to 1885, after his long working hours, he attended business college. His pay was so low (\$10 a month) that he was forced to find other sources of income, including watch and clock repair, to pay his rent (\$14 a month).

His father was concerned about Ford's situation, and, in the hopes that his son would become a farmer, he offered him 40 acres of land next to the family farm. Ford accepted the offer, but he continued to pursue his love of working with machines. In fact, he constructed a machinist workshop on his farm—where he built his first two-cylinder internal combustion engine. During this time, he also developed his first automobile engine prototype, which weighed 500 pounds. His love of working with machines was so great that he abandoned the farm in 1891 and went to work for the Edison Illumination Company in Detroit.

Unlike his previous work in Detroit, he had professional success at his new job. As an engineer, he earned the high salary of \$100 a month. He invested much of his earnings and time to develop an internal combustion engine that could be used to propel a “horseless carriage” (soon to be known as the automobile). During his work with the Edison Illumination Company, he met Thomas Alva Edison (1847–1931), and the two men became lifelong friends. However, Ford's automobile project became so time-consuming that his boss at the Edison Illumination Company forced him to choose between his job and his project.

In 1899, Ford chose to leave the Edison Illumination Company and, with the financial backing of a wealthy businessman, established the Detroit Automobile Company. Due in part to disagreements with his investor, however, the company failed. After failing in business for a second time, in 1901, Ford raced his latest invention to victory against the fastest-known

automobiles as a publicity stunt. The publicity got businessman Alex Y. Malcomson's attention. With Malcomson's financial backing, in 1903, Ford founded the Henry Ford Company (which was later renamed Cadillac) and the Ford Motor Company. That same year, more than 1,000 other automobile companies were founded. This created a lot of competition.

Ford was able to remain successful due, in large part, to his choice of competent assistants. For example, John and Horace Dodge (the Dodge brothers) who would later go on to establish their own Dodge automobile empire, worked for Ford. In 1903, the Ford Motor Company rolled out the Model A, which sold 1,700 that year. Ford frequently introduced new models, and he assigned letters of the alphabet to each of them.

After six years of designing and building automobiles for mass consumption, Ford was able to home in on methods (including the use of standardized designs and interchangeable parts) that allowed him to make reliable, easy-to-build, and cheaply priced automobiles. He pioneered the use of the moving assembly line in his automobile factories. In this arrangement, each worker was responsible solely for the assembly of a specific part, and the automobile was built by one worker at a time as it moved along the factory line. The use of the assembly line increased production. In turn, mass production of automobiles drove costs down.

Lower-priced automobiles increased sales and profits, because more people could buy them. In 1909, Ford introduced the Model T, which became his best seller. In just one year, 8,000 of them were sold. Ford kept producing the same basic model for almost two decades and sold 34,000 in 1910, 78,000 in 1911, and 730,000 in 1916. In 1918, he appointed Edsel Ford, his son, as president of Ford Motor Company. However, Ford kept control of the company while he ran for the U.S. Senate. Although Ford was bitter over his political defeat, the Ford family business was booming, and in 1919, it opened the doors to the River Rouge (Detroit) plant, the world's largest automobile factory.

In the 1920s, millions of Americans regarded Ford a folk hero, and there was serious talk among some party leaders about nominating him as a candidate for president of the United States, but he was unable to

garner sufficient political support. By the late 1920s, competitors like General Motors and Chrysler were building automobiles that provided comfort, style, and status. As a result, Ford sales dropped dramatically. In 1927, Ford reluctantly stopped the production of the Model T. The next year, he introduced an updated Model A, but the new design failed to dominate the market like the Model T had done. To make matters worse, he lost most of his best assistants.

Ford had always been narrow-minded and stubborn, but with age, the negative side of his personality began to dominate his decisions. During the Great Depression (1929–1939), Ford refused to cooperate with President Franklin D. Roosevelt’s New Deal programs that were intended to put millions of unemployed Americans back to work. Having developed a reputation in the 1920s for paying his workers a competitive wage of five dollars a day, during the 1930s, labor leaders accused him of paying the lowest wages and maintaining the worst working conditions in the industry. Ford was willing to use violence to block union activities. When the national press criticized his actions, he either threatened to sue or sued for slander.

Perhaps the World War II era was the lowest point of Ford’s legacy. Since things were not going well for him, he believed that he was a target of a conspiracy. It was during this time that he publicized his prejudice against the Jewish people. In 1938, he garnered considerable suspicion of being a Hitler sympathizer when he accepted the Grand Service Cross of the Supreme Order of the German Eagle (the highest honor given by Germany to distinguished foreigners) from the Nazi government.

As early as the Model T era, the automobile’s importance to the economy was tremendous. Automobile manufacturing created many new jobs in various industries, including glass, rubber, steel, and textile. Workers were employed to assemble, inspect, and sell automobiles. With increasing numbers of automobiles on the road, new streets, hotels, and gas stations had to be built. The gasoline, oil, and tire industries expanded. Automobile mechanics were needed to do repairs, and so on. In short, the automobile became an important facet of the economy because it was intertwined with many other industries and professions.

“Fordism,” the term used to describe Ford’s business philosophy, involved harnessing machines, cutting costs by increasing production (economies of scale), and the constant quest for the greatest control over work steps and output. Critics charged that Fordism dehumanized workers. Principally, the use of the assembly line required workers to do machine-like (identical, repetitive, and standardized) motions. This kind of factory work environment was critically depicted in several popular motion pictures, including Charlie Chaplin’s *Modern Times* (1936).

In 1943, Edsel died, and Ford once again became the company’s president. Two years later, he relinquished complete control of his company, and Henry Ford II, his grandson, assumed the presidency. Ford died from a massive cerebral hemorrhage at his Fair Lane estate in Dearborn on April 7, 1947. His legacy as an important American innovator was secure. However, some significant events tarnished his image. Ironically, it was not until after his death that an automobile craze swept the nation, which once again brought tremendous prosperity to the Ford Motor Company.

Rolando Avila

See also Assembly Line; Automobile Technologies (Pre–World War II); *Vol. 2, Sec. 1*: Edison, Thomas

Further Reading

- Curcio, Vincent. 2013. *Henry Ford*. New York: Oxford Press.
- Ford, Henry. 1922. *My Life and Work*. New York: Doubleday.
- Gelderman, Carol. 1981. *Henry Ford: The Wayward Capitalist*. New York: Dial Press.
- Nevins, Allan, and Frank E. Hill. 1954. *Ford: The Times, the Man, the Company*. New York: Scribner.

Freon

“Freon” is a trademark name for a family of chlorofluorocarbons (CFCs). It was first synthesized by Belgian chemist Frederic Swarts. American inventor and engineer Charles Kettering and Thomas Midgley, an

engineer and chemist, led a team working for General Motors that significantly improved on CFC synthesis to create a less toxic refrigerant than ammonia.

Freon exists as a slightly toxic gas or liquid that is nonflammable. Freon is a brand name that encompasses a number of chlorofluorocarbons; however, other chlorofluorocarbons exist outside of the Freon brand, such as R-22. Chlorofluorocarbons (CFC) including Freon have been primarily used as aerosol propellants in the past but now primarily as refrigerant. The earlier versions of chlorofluorocarbons used contained chlorine and were partly responsible for depleting the ozone layer. The newer chlorofluorocarbons have changed ingredients to be more fluorine based and no longer deplete the ozone layer.

Refrigerants until 1929 relied on toxic and occasionally flammable gases such as sulfur dioxide, ammonia, and methyl chloride. During the 1920s, there were multiple reported cases of methyl chloride leaking from refrigerators and causing death due to asphyxiation. Owners of refrigerators at the time became alarmed and put them in the backyard for safety.

DuPont, Frigidaire, and General Motors worked in collaboration to find a safer means of achieving refrigeration. Thomas Midgley, with the help of Charles Kettering, invented the compound that would become known as Freon in 1928. CFCs find common use in industrial and commercial settings, aiding in refrigeration and cooling. Freon contains fluorine and carbon, which associate it with the group of aliphatic organic compounds. Freon appears colorless and nonflammable in both its liquid and gas states. CFCs are dangerous if inhaled in a sufficient amount and can cause a number of physical issues, so in many applications, an irritant is added to make detection of a leak noticeable.

In the United States, the first patent for Freon was issued to Frigidaire at the end of 1928: patent number 1,886,339. The new CFC was considered so safe that inventor Thomas Midgley demonstrated that he could inhale a lungful of the compound and exhale it onto a candle flame, proving that it was both nontoxic and nonflammable. Currently, the trademark “Freon” is owned by Chemours Company.

CFCs are no longer found in household products, such as hairspray, due to their negative effects on the

ozone layer. However, CFCs are still currently found in many products in and around the home, such as home and auto air-conditioners and refrigerators. Freon is also used in industrial refrigeration.

Joshua McPhail

See also General Motors (GM); Kettering, Charles F.; Midgley, Thomas; *Vol. 1, Sec. 2: Vapor-Compression Refrigerator*; *Vol. 2, Sec. 1: DuPont Company*

Further Reading

Bjorn, Lydia. 2015. *How the Refrigerator Changed History. (Essential Library of Inventions)*. New York: Essential Library.

Peavitt, Helen. 2017. *Refrigerator: The Story of Cool in the Kitchen (Science Museum)*. London: Reaktion Books.

Galvin, Paul Vincent (1895–1959)

Paul Vincent Galvin is credited with creating the mass production process of inexpensive automotive radios. He and his brother Joseph cofounded a business that grew into the large telecommunications company Motorola, which derived its name from his first popular product: the Motorola 5T71 radio.

Born in Harvard, Illinois, on June 29, 1895, Galvin studied at the University of Illinois before being drafted into the army at the start of World War I. In 1928, Galvin and his brother started a battery eliminator (a product used to connect radios to electrical output) company and named it Galvin Manufacturing.

By 1929, with the combination of the recent stock market crash and increasing popularity of plug-in radios, Galvin Manufacturing began to fail. To remain in business, Galvin looked to the application of radios in the automotive industry. Galvin formed a team of engineers from the neighboring radio parts company to design an affordable radio that fit appropriately into an automobile dashboard.

In the development of the automotive radio, numerous issues arose, including in maintaining a strong signal and properly securing the radio inside the automobile as it was in motion. Eventually, the team developed the product far enough to have a

working prototype, which Galvin presented at an automobile convention. There he received a sufficient number of orders to continue development of the radio, allowing the company to remain financially stable.

The finished product became known as the Motorola 5T71, named by Galvin as a contraction of the term “motorized Victrola.” The product became so popular that it became synonymous with the company, which eventually legally adopted the name.

Rosanne Welch

See also Radio; Triode Tube; *Vol. 2, Sec. 3: FM Radio*; Lamarr, Hedy

Further Reading

Lendino, Jamie. 2012. “The History of the Car Stereo.” *PCMAG*. February 10. <http://www.pcmag.com/article2/0,2817,2399878,00.asp>, accessed August 29, 2018.

“Motorola Starting with His Earliest Foray into Car Radios, Paul Galvin Kept His Electronics Company Tuned in to New Waves of Technology with Remarkable Frequency.” 2003. *CNN Money*. April 1. http://money.cnn.com/magazines/fsb/fsb_archive/2003/04/01/341018/index.htm, accessed August 29, 2018.

Gas-Powered Turbine Engine. See Turbine Engine, Gas Powered

General Motors (GM)

Founded by William C. Durant and Charles S. Mott in 1908, General Motors (GM) is one of the oldest and largest automobile manufacturing companies in the world. The company once operated in 35 countries, marketing 12 brands of vehicles, including Chevrolet, Buick, Cadillac, and GMC Truck. From 1931–2007, it was the world’s leader in car sales. It withstood the Great Depression and contributed to America’s victory in World War II. GM was the first to fit cars with electric starters, eight-cylinder engines, automatic transmissions, and antilock brakes. It also brought

back electric cars. And even though it was temporarily forced into bankruptcy during the Global Recession of 2009, General Motors continues to operate both in the United States and around the globe.

GM was the collective brainchild of two Michigan horse carriage makers, William Durant and Charles Stewart Mott. In 1890, Durant founded a horseless carriage company and in 1904 became the general manager for Buick. Mott merged his company, which made bicycle wheels, with Buick. In 1908, Durant opened General Motors as a holding company and the next day acquired Buick. By 1910, Durant and General Motors also purchased Oldsmobile, Cadillac, Pontiac, and the Reliance and Rapid motor vehicle companies. Reliance and Rapid were truck makers and would become the foundation of GMC, GM’s truck division. GM also tried to buy the Ford Motor Company. Durant offered to pay \$8 million for Henry Ford’s business, potentially overextending GM’s economic capabilities. GM’s board wasn’t pleased, and Durant was fired. In 1911, Durant cofounded Chevrolet with Louis Chevrolet.

Shortly after Durant’s dismissal, GM began to issue stock. Pierre du Pont, the Delaware-based industrialist and a Durant ally, began buying up the stock to underwrite a takeover. GM’s board discovered what was happening, but it was too late. Du Pont had a majority of the shares, and Durant was returned to power. He immediately promoted du Pont to chairman of the board. Durant also added Chevrolet to the GM stable.

The presence on GM’s board of movers and shakers such as Durant, du Pont, and Charles Stewart Mott, plus a booming U.S. economy aided by the country’s involvement in World War I, not only affected GM’s bottom line but also the company’s profile. By 1918, its workforce had swollen to 85,000. Many workers had come from Southern states, a part of the country low on industry and high on unemployment. As the new workers arrived, lodging became an issue. GM spent millions on employee housing to accommodate the growing workforce. Another GM innovation was to establish a retirement system similar to what many today would recognize as a 401k. Employees donated a portion of their wages to a retirement fund, and GM matched it dollar for dollar. It also took steps to secure

its corporate future by snapping up auto parts manufacturers. By vertically integrating supply and manufacturing, Durant and the other members of GM's leadership ensured that the corporation would always have a steady stream of parts to help build its cars.

The end of World War I produced not only peace but also economic recession. Sales of cars and trucks stalled. For the second time in less than a decade, Durant was forced out. The expulsion was driven in part by Pierre du Pont, the very man who had helped underwrite Durant's return in 1916. Du Pont chose Alfred Sloan, a member of GM's board and the president of one of the parts manufacturers GM had purchased, as the company's new president. As head of GM, Sloan introduced concepts such as annual styling changes, which called for year-over-year appearance adjustments in GM products, and planned obsolescence.

Planned obsolescence was the notion of designing a product with an artificially limited window of use so that it might eventually seem unfashionable. The theory was that if annual styling changes made a new Chevrolet or Buick appear more attractive than last year's model, consumers might upgrade. Sloan also introduced a system that encouraged customer loyalty, something he termed the "ladder of success." He created a model and pricing hierarchy from Chevrolet to Pontiac to Oldsmobile, Buick, and finally Cadillac. Thus, GM could provide a car to suit every consumer's preference and price range, keeping customers' money and loyalty inside the GM family. These innovations catapulted GM into the lead among U.S. carmakers. Sloan also expanded the activities of GMAC—the General Motors Acceptance Corporation—a financial bureau within GM to provide financing to potential car owners featuring affordable monthly payments.

After weathering the Great Depression and contributing to the Allied victory in World War II, General Motors's path continued to feature expansion and innovation. It achieved the distinction of being the largest corporation in the United States. It also continued to offer new vehicle innovations such as the Corvair, America's first postwar rear-engine compact, and the Vega, a subcompact featuring an aluminum engine designed to reduce weight and increase fuel efficiency.

By the 1980s, GM was building more pickup trucks and SUVs—sport utility vehicles—a strategy that succeeded until consumers' desire for smaller, more fuel-efficient cars returned in the 21st century.

GM's most daring leap in terms of product innovation was its commitment in the 1990s to produce electric vehicles. The EV1 was the first electric vehicle to be offered by an American carmaker. It was available on a lease-only basis to consumers in targeted cities around the United States, which had established strict auto emissions standards. Although consumer reaction was favorable, GM discontinued production in 2002, citing relaxations in emission standards, the lack of available charging stations, and promising technological advances in super-low-emission, natural gas, and hybrid vehicles.

The problems that GM encountered trying to introduce electric cars were consistent with the other challenges the automaker faced in the last third of the 20th century. It responded with new products and global expansion. It found success selling cars in China and Brazil, but it also found that to succeed in other markets, it needed to be leaner and more efficient. GM reorganized when the Great Recession of 2008 struck. Cars sales plummeted, and credit evaporated. The company negotiated a bridge loan from the U.S. Treasury, but it wasn't enough, and GM filed for bankruptcy in 2009. A downsized GM emerged later that year, sporting familiar brands and a more global emphasis. Today, more than 70 percent of GM's sales come from outside the United States.

John A. Morello

See also Automobile Technologies (Pre–World War II); Ford, Henry; Petroleum Industry (Pre–World War II); *Vol. 1, Sec. 3*: Goodyear, Charles; *Vol. 2, Sec. 1*: du Pont, Pierre; DuPont Company; *Vol. 3, Sec. 1*: Electric Car

Further Reading

Cray, Edward. 1980. *Chrome Colossus: General Motors and Its Times*. New York: McGraw-Hill.

Maynard, Micheline. 2003. *The End of Detroit: How the Big Three Lost Their Grip on the American Car Market*. New York: Random House.

Gilbreth, Lillian (1878–1972)

Lillian Gilbreth invented the egg keeper and butter tray for inside refrigerator doors and the foot-pedal trashcan. She combined all the perspectives of an engineer, a psychologist, a wife, and a mother into her work. By applying the principles of scientific management to household tasks, Gilbreth wanted to provide women with shorter, simpler, and easier ways of doing housework to enable them to seek paid employment outside the home.

Gilbreth was born Lillian Moller in Oakland, California, the second of 11 children. She graduated from University of California, Berkeley in 1900 with a bachelor's degree in English literature and was the first female commencement speaker at the university. After finishing the first year of her PhD, she met Frank Gilbreth. The couple married on October 19, 1904. Gilbreth earned her PhD in psychology in 1915 from Brown University while also giving birth to four children. At Brown, she pioneered in industrial management.

Lillian and Frank Gilbreth applied their scientific management principles to the running of their household and a consulting businesses. The couple also wrote books together, but Lillian was left off as coauthor simply because she was a woman and could compromise their credibility despite having a doctorate. She was later described in the 1940s as “A genius in the art of living.”

Until 2005, she was the only woman awarded the prestigious Hoover Award given by five leading engineering organizations recognizing great, unselfish nontechnical services by engineers to humanity. Her work as a consultant to corporations applying psychology to solve problems in areas such as office equipment, household appliances, hospitals, and sports led her to come up with new designs and inventions to make work and life easier. She also filed patents for an improved electric can opener and the wastewater hose for clothes washers. As an industrial engineer working at General Electric, she interviewed over 4,000 women to design the proper height for stoves, sinks, and other kitchen fixtures as she worked on improving kitchen designs for modern lifestyles. While these were her most popular contributions, she

was known for having a great career while being the mother of 12 children.

Throughout Gilbreth's lifetime, she received 20 honorary degrees and also was the first female member of the Society of Industrial Engineers. A few years after retiring, she passed away, but she had proven that women could have a happy family life as well as a fulfilling and meaningful career at the same time.

Greg Salcido

See also *Vol. 1, Sec. 3*: Dustpan; Electric Stove

Further Reading

Gilbreth, L. 1998. *As I Remember: An Autobiography*. Norcross, GA: Institute for Industrial Engineers.
Lancaster, Jane. 2004. *Making Time: Lillian Moller Gilbreth—A Life Beyond “Cheaper by the Dozen.”* Hanover, NH: University Press of New England.

Gramophone/Victrola

A gramophone or phonograph is a piece of technology capable of recording and playing sound by means of a stylus needle vibrating in grooves carved into a cylinder or disc whose rotation is powered by hand or a clockwork motor. Introduced in 1877 by American inventor Thomas A. Edison, the technology has undergone numerous transformations and changes in name. The phonograph, talking machine, Victrola, record player, hi-fi, or turntable was the predominant method of recorded music playback until the last quarter of the 20th century. By the 1930s, the rise of radio altered the technological and business dynamics for how Americans listened to music.

Due to different patents and a varied manufacturing history, the gramophone has entered into common parlance under different names, sometimes under a variety of names at the same time. The word “phonograph” was supposed to be applied only to Edison cylinder machines and was a neologism combining the Greek for “sound” (*phone*) and “writing” (*graph*). However, by the turn of the 20th century, “phonograph” was increasingly applied to any device regardless of manufacturer or type. The word “gramophone,” which originally identified Emile Berliner's flat-disc

device, was a close inversion of the word “phonograph.” This may have been done in part because “phonography” had already existed as a system of phonetic shorthand since the 1850s. “Gramophone,” “graphophone,” “phonograph,” and “zophone” were among many trademarked names often generically referred to as “talking machines.”

Despite improvements in materials and sound quality, the basic premise of the phonograph remained fairly consistent throughout its day. Sound waves were engraved on a record to move the stylus or needle up and down in a format called “hill and dale.” By the early 20th century, this was updated to allow the needle to vibrate horizontally. The movements of the needle on a record cause sound waves, which are amplified by a small tone arm vibrating a flexible diaphragm. The sound waves are then further amplified by traveling through a metal arm and horn. For much of the early history of phonographs, this horn was mounted on the exterior, giving “talking machines” their distinctive large funnels.

Victor Talking Machines devised a model that had the horn on the inside of the cabinet, which had the added benefit of volume control by opening and closing the cabinet doors. This innovation was marketed as the “Victrola,” and it soon became a common term for any phonograph with an interior horn. This type of phonograph was widespread by the 1910s and especially during the 1920s, when upper-middle-class and elite Americans could afford this expensive status symbol.

The earliest phonographs were powered by hand crank, the operator having to maintain suitable repetitive speed for the music to play consistently. As time progressed, wind-up clockwork motors were attached to the turntable to regulate speed. By the 1920s, models were introduced that used an electric motor to rotate the turntable. These electric models were often united with the expanding technology of radio to make such products as Victor Talking Machine’s “Radiola.”

Thomas A. Edison devised the first phonograph to play grooved cylinders covered in a layer of tinfoil. While Edison and other early innovators considered using flat discs in their phonographs, they rejected the idea as less efficient for the business transcription purposes they had originally intended for their invention.

The 1880s witnessed, under the guidance of Emile Berliner and Alexander Graham Bell, the use of flat discs made of wax and metal, and finally shellac. This new flat disc was more versatile and easier to reproduce on a large scale than cylinders. Played at 78 RPM (rotations per minute), these records were the ancestors in shape and format of all later record types.

The phonograph drastically transformed how Americans obtained and listened to music, plays, operas, and even the speeches of eminent persons. In the 1890s, most major cities had “phonograph parlors” where customers could request to hear music. Live performers could now record their material in a studio and have upward of 150 copies stamped on records. As copying technology improved, so too did the number of records mass-produced and placed on the market. The leading companies realized that the best way to sell phonographs was to create a line of recorded music popular with the American public.

Many contemporary “record labels” also made phonographs, including Columbia Records and Victor Talking Machines. For Victor, the color of the label determined the nature of the music: “red seal” for prestigious classical artists and “black seal” for popular music. Each company vied with the others to sign important artists that it could advertise as exclusively recording for it. The famous opera tenor Enrico Caruso was a highly sought-after performer who popularized opera and classical music in middle-class homes. Phonograph records also built the careers of great comedic acts like Van and Schenck, popular artists like Billy Murray and Al Jolson, and eminent singers like Alma Gluck and John McCormack. So long as phonograph recording was done acoustically (that is, without the aid of an electric microphone), recording artists and bands would have to crowd close to a horn and perform with a limited dynamic range.

The 1920s witnessed the rise of radio as a medium accessible to American families that could also provide a clearer performance compared to phonographs. Victor and Columbia, rivals with the greatest share in the phonograph market, struggled to maintain their supremacy. In 1925, most phonograph companies switched from acoustic to electric recordings in an effort to increase the quality and range of their product. Victor marketed these records as “orthophonic”

and released a new line of Victrolas with higher sound quality.

Improvements in recording could not recover the faltering preeminence of the phonograph companies. Edison Records folded during the Great Depression, and Victor was acquired by the Radio Corporation of America in what was seen as a sign of the changing times. The age of the talking machine had yielded to that of the radio.

Sean P. Phillips

See also *Vol. 2, Sec. 1*: Bell, Alexander Graham; Berliner, Emile; Edison, Thomas; Phonograph

Further Reading

Kenney, William Howland. 2003. *Recorded Music in American Life: The Phonograph and Popular Memory, 1890–1945*. Oxford: Oxford University Press.

Millard, Andre. 1995. *America on Record: A History of Recorded Sound*. Cambridge: Cambridge University Press.

Gumball Machine

Gumball machines collect coins and then dispense pieces of chewing gum usually formed into balls. The machines often include a clear sphere filled with gum-balls, and this sits on top of a metal base. A coin inserted into a slot in the base results in the gum being dispensed into a chute at the bottom of the machine. It was likely designed by Thomas Adams, who had partnered up with Antonio López de Santa Anna to make and market Mexican chicle.

The rapid growth in popularity of chewing gum led to the creation of the first gum dispenser in 1888. These machines were strategically placed in areas with a lot of foot traffic. This machine was said to be one of the first vending machines operated by coin. In 1907, the world was introduced to the first gumball machine. Not only was the shape of the dispenser different from what Adams had invented, but also the gum itself, which was spherical. The gumball machine remains a familiar sight 110 years later.

Dannela Azul Valencia

See also Life Savers Candy; *Vol. 1, Sec. 3*: Hand-Cranked Ice Cream Maker; *Vol. 2, Sec. 1*: Cotton Candy Machine

Further Reading

Adams, Thomas. 1871. Improvement in Chewing Gum. U.S. Patent 111,798, issued February 14, 1871, and reissued February 26, 1880.

“Bubble Gum Machine—Gumball Machine History.” *Chewing Gum Facts*. <http://www.chewinggumfacts.com/chewing-gum-history/bubble-gum-machine/>.

Loohauis, J. 2001. “Pop! Culture.” *Milwaukee Journal Sentinel*, March 20.

Tsuruoka, D. 2011. “Thomas Adams’ Gum Was an Idea That Stuck: He Used Imagination to Create a Candy Empire.” *Investor’s Business Daily*, December 28.

Hewitt, Peter C. (1861–1921)

American electrical engineer Peter Cooper Hewitt invented the first mercury vapor lamp in 1901. The mercury vapor lamp is a gas discharge lamp that shoots an electric arc through vaporized mercury, generally in a small tube mounted within a larger glass bulb, to produce light. The outer bulb provides both thermal insulation and protection for people, as the light produces ultraviolet radiation. Mercury vapor lamps are generally more energy efficient than both fluorescent and incandescent lights, and they have a long lifetime. They are commonly used in sports arenas, factories, warehouses, and as streetlights.

Hewitt was born in New York City in 1861 to Abram and Sarah Hewitt. He went to Stevens Institute of Technology and the Columbia University School of Mines, where he received an honorary doctorate of science. Most of his life was spent pursuing scientific innovation by using the wealth from his grandfather, Peter Cooper. Hewitt eventually realized that an electric current could pass through sealed mercury gas. His first lamps had to be started by manually tilting the tube to let the two electrodes touch in the liquid mercury. He then created an electrical ballast for his lamps to efficiently start the light. These initial lamps produced blue-green light. Hewitt solved this off-color



Electrical engineer Peter Cooper Hewitt invented the first mercury-vapor lamp in 1901. The son of a New York City Mayor, he later worked on one of the first successful precursors of the cruise missile. (Library of Congress)

light by making a transformer that added red rays of light, producing a more incandescent effect. The transformer he added produced a powerful ultraviolet light that became useful in some chemical processes, sterilization, and therapeutic practices.

Hewitt produced several other inventions, such as the first rectifier that could convert alternating current to direct current without mechanical means. Today, except for some high-power applications, it has been replaced by power semiconductor devices.

He married Lucy Work in 1887, though he later divorced her; they had no children. He married his second wife, Mary Andrews Brugiere, in 1918, and together they had one daughter, Anne Cooper Hewitt. Hewitt died in 1921, in Paris.

After Hewitt's death, the vapor lamp was improved by adding a fluorescent coating on the inside of the tube, which produced white light as it absorbed the ultraviolet light and radiation. This later led to the creation of fluorescent lights, which are low-pressure mercury vapor gas discharge lamps.

The mercury in the tube is liquid at normal temperatures, so mercury vapor lamps require a starter to heat the mercury. This process is slow and takes four to seven minutes. In addition to needing a starter, these lamps require a ballast to limit the current through them, as the lamps have negative resistance to current. If the current is not limited, the lamp will destroy itself. Mercury vapor lamps are still used commonly as streetlights, with high-pressure lamps being used in most projectors as well as in molecular spectroscopy.

Richard Matthew Musquiz

See also *Vol. 1, Sec. 1: Street Lighting; Vol. 2, Sec. 1: Edison, Thomas; Electric Lightbulb; Vol. 3, Sec. 1: LED Lights*

Further Reading

Roach, Craig R. 2017. *Simply Electrifying: The Technology That Transformed the World, from Benjamin Franklin to Elon Musk*. Dallas: BenBella Books.

Hoosier Cabinet

The Hoosier cabinet is a piece of kitchen furniture that was popular in the early 20th century, designed to provide compact storage and increased workspace for American kitchens.

In the late 1800s, the Hoosier Manufacturing Company was focused on cabinetry. Homes did not have built-in cabinetry, so the company created the Hoosier cabinet, a cupboard created in New Castle, Indiana. An existing piece of furniture, the baker's cabinet, was altered to house different compartments

of different sizes and equipped with a variety of accessories from flour jars and dispensers to spice bottles. The cabinets generally had three pieces: a base with doors on the front and drawers, a midsection that sat on the workspace and provided a shallow area for small containers, and a top compartment with doors and shelves. Cabinets also had a shelf that slid out from the cabinet itself. Some versions of the cabinet came with tea canisters, a salt box, and jars. Cards on the door interiors provided cooks with measurement conversions, and the doors were a place to keep recipes.

Since most homes are now built with furniture, the Hoosier cabinet has turned from being a necessity into a supplementary piece of furniture.

Raul Monzon

See also Blender; Bread Slicer and Wrapping Machine; Gramophone/Victrola; Pop-Up Toaster

Further Reading

Hiller, Nancy R. 2009. *The Hoosier Cabinet in Kitchen History*. Bloomington: Indiana University Press.

Hydroelectric Power

Hydroelectric power is an alternative method to fossil fuels, harvesting power by utilizing moving water. Facilities such as dams are the main method of harvesting energy from water. It is a renewable energy that generated 6.1 percent of power in the United States in 2015 and makes up a quarter of its total renewable energy. The International Energy Agency claims that hydroelectric power generates 16 percent of total electricity generated globally.

As early as the 12th century, there were designs for harnessing water to create energy. Al-Jazari, an engineer, wrote of several machines that used water for power, such as water mills. He developed a water supply system that distributed water to mosques and hospitals.

A surge of inventions came from the Industrial Revolution in Britain around the 18th century that used water and steam as power. One invention of the time was the water frame, which was used to make

cotton thread. Around 1712, Thomas Newcomen invented the first piston steam engine. It allowed for people to mine coal in areas that had been previously flooded. The water mill resulted in benefits to other occupations: gristmills were created to grind grain into flour. Sawmills also utilized water power to push logs through saw blades. These early methods eventually led to the use of turbines, which help produce energy for households today.

In the 19th century, the United States used water to balance heavy cargo so that it could travel inclined railroads. In the 1920s, the Federal Power Act was established to develop other hydroelectric projects. Facilities that generated power, as a result, had additional purposes such as flood control and irrigation. One example of this would be the Hoover Dam, built under the auspices of the Works Progress Administration as part of Franklin D. Roosevelt's New Deal. By 1939, the dam became the largest hydroelectricity facility in the world. On average, the dam has generated 4.2 terawatt-hours (TWh) per year since 1947 and has recently generated 3.6 TWh in 2015.

Dams like the Hoover and others not only corralled water for agricultural irrigation but created hydroelectric power. Dams brought electricity to many areas of the country for the first time, allowing people in rural and Western states to buy radios, electric lights, washing machines, and the like. However, dams also caused environmental disasters, both by depriving downstream areas of water and flooding natural areas. Many a hydroelectric dam has been immensely controversial. The Marble Canyon Dam, for example, was planned for the Colorado River, upriver from the Hoover Dam and near the Grand Canyon. Environmental and Native American activists stopped the dam from being built.

Hydroelectric power produces a fraction of the electricity that the United States consumes. In 2014, 4,146 TWh were distributed for residential, commercial, and industrial use. Corporations were created with the help of the government in the 1930s to help in the realm of energy manufacturing, which resulted in the Tennessee Valley Authority. The TVA was active in several Southeastern states and created numerous dams. Another government-owned company is the Bonneville Power Administration; in 1937, the

company was told to sell the energy it created to other companies and states.

Early U.S. hydroelectric power generators were implemented to supply lighting; however, the generators had a limit of 10 miles that power could be sent to. With further development, different methods were created to generate electricity besides with dams, which use the potential energy of the captured water. Pumped storage requires two reservoirs, one at a higher elevation than the other, with a turbine in the paths of both to create energy whenever water passes between the reservoirs. In run-of-the-river setups, there is no captured water; thus, only water flowing downstream is used to generate electricity, but there is the potential for oversupply, which leads to unused electricity. Tidal power stations use the levels of the tide that change over the course of a day to generate power.

Since hydroelectric stations are built next to bodies of water, they can produce as much energy as necessary to meet demand. Likewise, the facilities may be slowed down during periods when a surplus of power is generated. These stations emit the least greenhouse gases compared to power created from nuclear energy and fossil fuels. Since these facilities require turbines and water to fulfill their purpose, they create little pollution and are low maintenance, making them an efficient energy producer.

However, there are disadvantages to these stations. Large ones such as the Hoover Dam not only damage the ecosystem around them, but today, they are not being utilized as much. In 2014, the dam was only used when necessary, as a drought had reduced the amount of water in Lake Mead neighboring the dam. Construction costs may be too great for dams such as these to be left almost unused. The drought hurt energy production at the Hoover Dam, a particular problem in light of climate change realities. In California, years of drought have forced the use of natural gas as energy in the place of hydropower. Some areas may find themselves with an abundance of water that may not be fully utilized. The unreliability of hydroelectric power in some areas and the lack of feasibility of it in others has created a larger push for solar and wind energy.

Raul Monzon

See also *Vol. 1, Sec. 2: Steamboat; Vol. 3, Sec. 1: Hydrogen Energy; Vol. 3, Sec. 2: Nuclear Energy/ Nuclear Power Plants; Solar Energy; Wind Energy*

Further Reading

Manganiello, Christopher J. 2015. *Southern Water, Southern Power: How the Politics of Cheap Energy and Water Scarcity Shaped a Region*. Chapel Hill: University of North Carolina Press.

Monition, Lucien. 1984. *Micro Hydroelectric Power Stations*. New York: Wiley.

Jacob, Mary Phelps (1891–1970)

Mary Phelps Jacob, also known as Caresse Crosby or Polly Jacob, was the first recipient of a patent for the modern bra. As fashions of the Edwardian period changed to use more loose-fitting and sheer fabrics, the era of the corset was coming to a close. Jacob was instrumental in shifting American society from the corset to her prototype of the modern bra.

Born in 1891, Jacob grew up in New Rochelle, New York. She had a privileged childhood that included private school, dancing school, and horseback-riding school. Jacob grew up in the era of the corset, a garment that sometimes narrowed an adult woman's waist to 16 or fewer inches. Corsets had been the primary means of undergarment support for women for over 350 years, but during the 1880s and 1890s, shifting fashions and cultural attitudes led to several attempts to make the corset more comfortable. This included designer Susan Taylor Converse's "Union Under-Flannel," a wool corset that had no bones, eyelets, lace, or pulleys. In 1889, Herminie Cadolle modified the corset into a two-part undergarment known as the "Well-Being," with the top half supported by the shoulders and the bottom remaining a corset for the waist and rear. And in 1893, the first brassiere had been invented by Marie Tucek in a design that included separate pockets for the breasts, shoulder straps, and hook-and-eye closures. The design never became popular.

In 1910, Jacob purchased a sheer evening gown, one of the latest fashions, for a social event. While getting ready for the event, Jacob discovered that her

corset's whalebones visibly poked out from the gown's plunging neckline and sheer fabric. Working with her maid, Jacob fashioned a prototype of the modern bra, made with two silk handkerchiefs, pink ribbon, and cord. At the social event, Jacob's new undergarment—which made wearing the sheer gown possible—was hailed by friends and family, who asked Jacob to create similar garments for them. Jacob was soon asked to produce the garment for a fee and realized that she had a potential business venture.

Jacob applied for a patent for her "brassiere" in February 1914, noting in her application that her invention provided

a garment which has no back and therefore does not interfere with any design of evening gown that may be chosen; one which is capable of universal fit to such an extent that for commercial handling it need be made in but few sizes, with reasonable certainty that the size and shape of a single garment will be suitable for a considerable variety of different customers; and . . . is characterized by extreme simplicity by freedom from bones to that it may be finished with laces or embroideries for wear beneath a sheer waist or diaphanous gown, and which when worn is both comfortable and cool and so efficient that it may be worn even by persons engaged in violent exercise such as tennis. (Jacob, 1914)

The patent was issued on November 3, 1914, for a "Backless Brassiere" that was lightweight, soft, and separated the breasts naturally. Her design did not support the breasts but rather flattened them, which suited the emerging fashions of the time. It was constructed of two pieces of cloth joined by a seam extending vertically between the breasts. The two pieces of cloth were sewn at an angle and connected around the back by tape or string supported by the shoulders and down under the arms.

Jacob opened a business in Boston, called the Fashion Form Brassiere Company, to manufacture the Backless Brassiere. She primarily employed

women in it. Her business was largely unsuccessful, though, and Jacob sold the company and her patent to Warner Brothers Corset Company for \$1,500 and moved to Europe with her husband. Jacob would never work on the bra again, instead becoming a bohemian and publisher of contemporary writers. She died in 1970.

Jacob's invention would change fashion for women during the 20th century, however. During World War I, when the U.S. War Industries Board asked women to stop buying corsets to free up metal for war production, consumer acceptance of the brassiere—nicknamed the “bra”—skyrocketed. Jacob's brassiere, now sold by Warner, enjoyed widespread use.

Tiffany Rhoades

See also *Vol. 1, Sec. 3: Hoop Skirt; Vol. 2, Sec. 1: Jockstrap*

Further Reading

Farrell-Beck, Jane, and Colleen Gau. 2002. *Uplift: The Bra in America*. Philadelphia: University of Pennsylvania Press.

Hamalian, Linda. 2009. *The Cramoisy Queen: A Life of Caresse Crosby*. Carbondale: Southern Illinois University Press.

Jacob, Mary P. 1914. Brassiere. U.S. Patent 1,115,674, filed February 12, 1914, and issued November 3, 1914.

Kettering, Charles F. (1876–1958)

Engineer and inventor Charles Kettering was the head of research at General Motors for 27 years, founder of the Kettering Foundation, and cofounder of Delco. He held 186 patents. Some of the most important inventions he created are the electrical starting motor, leaded gasoline, the first colored paints used for mass-produced automobiles, a precursor to credit cards, the electric cash register, Freon, and the world's first aerial missile. In addition, he improved the two-stroke diesel engine by increasing the ratio of the power produced to the weight of the engine, which replaced the four-stroke diesel engine.

Kettering was born in 1876 to Jacob Kettering and Martha Hunter on a farm in Ohio. When Kettering graduated high school, he worked as a teacher. As a student, he had bad eyesight, which gave him repeated headaches, eventually forcing him to quit studying a year after he entered college. This caused him to suffer from depression. He then started working as a foreman for a telephone line for two years. In this time, he met Olive Williams, whom he would marry in 1905. Eventually, his eye problems lessened, and he was able to return to school. He graduated from Oregon State University in 1904 with a degree in electrical engineering. He was hired by National Cash Register (NCR) to work in its research lab as their electrical inventor.

While working for National Cash Register, Kettering invented an easy credit approval system. This coupled existing telephones at the sales counters with solenoid-operated stamping machines at the central office, leading to his promotion to head an inventions department. He then proceeded to invent the electric cash register, and he later improved it for restaurant use so that it could divide the total price into subcategories.

While working at NCR, Kettering used his spare time looking for ways to improve automobiles. He eventually thought of using the starter in his cash register to replace the current automobile ignition system. This would increase the battery life of cars, which at the time needed to be replaced every few hundred miles. Soon after, Kettering and NCR's general manager, Edward Deeds, founded Delco to commercialize the new ignition system, and Kettering left NCR to focus on Delco.

Kettering then started working on the electrical starting motor. He improved the electrical system, designing a starter that could be its own battery and igniter. This innovation was introduced in the Cadillac 1912 model. In the next years, Kettering sold Delco to the United Motor Company for \$2.5 million, which then became part of General Motors and the foundation for GM Research Corporation. Kettering became the head of GM Research, a vice president of GM, and a member of the GM board. When GM transferred the majority of its research to Detroit, Kettering moved with them and stayed for

the rest of his life. He continued to invent until his death in 1958.

Richard Matthew Musquiz

See also Automobile Technologies (Pre–World War II); Freon; General Motors (GM)

Further Reading

Boyd, Thomas Alvin. 2002. *Charles F. Kettering: A Biography*. New York: Beard Books.

Lie Detector

The lie detector, also known as a polygraph, is the first technological instrument developed to measure human honesty. The lie detector is based on the premise that human beings produce physiological responses when lying and that those responses can be measured to determine a person's truthfulness. While the first lie detector looked very different from modern lie detectors, the premise and the physiological responses measured remain virtually unchanged.

While there is some disagreement over who invented the first lie detector, a Berkeley police officer, John Larson, is most frequently given credit for his machine developed in 1921. Influenced by the research and work of others, Larson, with the help of a lab technician, created a detector that simultaneously recorded blood pressure and breathing. Larson's lie detector was placed on a table about six feet long. Wires connected the machine to a blood pressure cuff on the interviewee's bicep and a rubber hose that was wound around the chest to measure the depth of breathing. The interviewee was instructed to sit still so that the machine would accurately record the person's physiological responses. Once the machine was turned on, the black recording paper began to turn, and two needles scratched the blood pressure and respiration measurements onto the paper. Then, Larson was ready to begin questioning. Larson devised a combination of relevant and irrelevant questions that required only yes and no answers. This combination helped to determine the person's truthfulness.

Several problems with Larson's lie detector were immediately apparent. First, it was extremely large

and not easy to transport. Second, the pressure cuff only permitted the interview to last six minutes before it became painful. Third, the results on the black recording paper were blurry and difficult to preserve. Finally, the transfer of information from the rubber tubes to the pens was unreliable and not very sensitive.

A number of improvements were made to Larson's lie detector. In the early 1930s, Leonarde Keeler (1903–1949) patented the Keeler Polygraph, the first portable polygraph that addressed many of the problems in Larson's lie detector. Keeler also added an additional testing component: perspiration (sweat). Over time, pneumatic sensors, which relied on air pressure, were replaced with electronic sensors, and these were eventually replaced by computerized sensors. In the 1990s, the scrolling paper was replaced by computer screens. Computerized algorithms were created to help the examiner interpret the results. In 2012, the American Polygraph Association began requiring a fourth measurement, which would record body movement as a countermeasure to "beating the machine."

While Larson invented the lie detector as a tool for police investigations, the courts have continuously denied their use in the courtroom. Banned from court proceedings, polygraph examiners found numerous other places for their machines to be useful. William Marston (1893–1947), who also introduced Wonder Woman to Americans in 1942, and Keeler were instrumental in introducing the lie detector to almost every aspect of American society. Marston envisioned a world where families might use home lie detectors to resolve disputes or women might test the honesty of potential husbands.

By the middle of the 20th century, millions of polygraph examinations were taking place each year. Law enforcement used the lie detector to streamline their investigations. Banks, department stores, insurance companies, and government agencies used it in employee hiring and investigations. Eventually, the machine went beyond determining truthfulness and was used to determine who could be trusted, to determine political loyalty, to eliminate petty theft, and to eliminate the third degree in investigations. Controversy over the increased use of the lie detector led to

the Employee Polygraph Protection Act of 1988, which led to a decrease in the number of tests conducted, especially in the private sector; however, exceptions continue to allow many tests to be conducted.

The lie detector continues to be an important technological invention in American society, although its successes and the American fascination with it have led to an increase in research to identify what other physiological responses are connected to lying and what machines we can use to identify truthfulness. In the 1960s, research began to focus on voice stress analysis, which detects changes in voice and tone. Since then, lasers have been used to detect muscular, circulatory, and other bodily changes. Facial thermal imaging identifies blood flow pooling around the eyes, and functional magnetic resonance imaging (fMRI) examines changes in the brain when a person lies. Despite all of these other tools, the lie detector first invented by Larson continues to be the most widely used form of lie detection.

Jessica Schmidt

See also Vol. 2, Sec. 1: Metal Detector

Further Reading

- Alder, Ken. 2007. *The History of an American Obsession: The Lie Detectors*. New York: Free Press.
- Bunn, Geoffrey C. 2012. *The Truth Machine: A Social History of the Lie Detector*. Baltimore: Johns Hopkins University Press.
- Grubin, Don, and Lars Madsen. 2005. "Lie Detection and the Polygraph: A Historical Review." *The Journal of Forensic Psychiatry & Psychology* 16, no. 2: 357–69.

Life Savers Candy

Life Savers brand hard candies were created in 1912 by Clarence Crane (1875–1931). A longtime business owner, Crane wanted to make a new type of candy that would not melt in summer heat. He had experience working with sweets, having owned a company that produced maple sugar. After experimenting with

various forms of hard candy, he developed the formula for Life Savers. He produced the candies by using a machine that made tablets and punching out a hole in the middle, thereby creating the distinctive life preserver shape that gave the Life Savers their name. He called them "Pep-O-Mint Life Savers," packed them in a cardboard tube, and marketed them as breath mints. Sales of Life Savers surged once the candies were marketed to bar owners for use by customers who wanted to mask the smell of alcohol and cigarettes.

Today, Life Savers brand candies are sold around the world and include fruit flavors, gummy textures, and even sour varieties.

Alberta M. Miranda

See also Vol. 2, Sec. 1: Cotton Candy Machine

Further Reading

- Mariani, Paul L. 2000. *The Broken Tower: The Life of Hart Crane*. New York: W. W. Norton.
- Weinstein, Bruce. 2000. *The Ultimate Candy Book*. New York: HarperCollins.

Marsh, Albert L. (1877–1944)

Albert Leroy Marsh, an American metallurgist, coined the alloy known as "nichrome." Composed of nickel, chromium, iron, and other trace elements, this metallic alloy was primarily used in the creation of heating elements. Due to its high electrical resistance and durability under high temperatures—which consequently yields a great amount of heat—the alloy, typically melded into the form of a wire, can be found as a safe igniter for fireworks, a blade for a hot wire cutter, or even as part of daily life tools such as toasters and hair dryers.

Born in August 16, 1877, Marsh was the eldest of three; he grew up in Pontiac, Illinois, but shortly moved with his family to Pana, Illinois. In 1901, Marsh graduated from the University of Illinois at Urbana-Champaign with a bachelor's degree in chemical engineering.

Marsh's eventual success with the nichrome alloy began as simple experimentation with alloys

of nickel and chromium on the side of his main work. In need of a place to work on his experiments, he was hired by William Hoskins, co-owner of the leading firm in chemistry known as Mariner & Hoskins.

While working for Mariner & Hoskins, Marsh created an alloy a few hundred times stronger than any others on the market. Dubbed originally “chromel,” the initial composition of the alloy was 80 percent nickel and 20 percent chromium. Marsh patented the alloy in 1906 but soon after sold the patent to Hoskins’s company, which had been renamed as Hoskins Manufacturing. His newfound success led him to a promotion as both a chief engineer and a general manager of the firm, and later in 1915, he became the president of Hoskins Manufacturing.

After the creation of the alloy, the company sought to apply it in its untapped market, which eventually led to the creation of the chromel wire. Most other metals used for conducting wires in the market required manufacturing into thin, fragile wires to create enough resistance to generate heat. Because the chromel wire did not have to rely on this—due to its high electrical resistance property—the wire was much sturdier than any other at the time. Thus, the company’s primary focus became the production of these wires.

Nichrome is widely used. Because the alloy produces heat when given an electrical surge, 21st-century manufacturers have used it as part of ignition systems for objects such as electric matches, fireworks, and igniters for model rockets. The wire is also typically used in ceramics as a support for the clay; its durability in intense heat allows the wire to support a sculpture while in the kiln. The alloy has been used to make heating coils for various appliances ranging from toaster ovens to some motorcycle mufflers to electronic cigarettes.

Peg A. Lamphier

See also Motorcycle (Pre–World War II); Pop-Up Toaster

Further Reading

Dugdale, J. S. 2016. *The Electrical Properties of Metals and Alloys*. London. Edward Arnold.

McKnight, William L. (1887–1978)

American businessman William L. McKnight’s career led him to the top of the 3M Company. During his later years, he became a philanthropist, creating the McKnight Foundation with his wife, Maude L. McKnight, in 1953.

William L. McKnight began his life on a South Dakota homestead on November 11, 1887. His parents were Joseph and Cordelia McKnight, who came to South Dakota seven years prior to build their homestead. McKnight attended Duluth Business University. Upon his graduation in 1907, he gained employment as an assistant bookkeeper for 3M. His starting salary at 3M was \$11.55 a week.

3M was a struggling company on the edge of bankruptcy when McKnight started his career there. During his early years of employment, he was known for his insistent ideas about creating better products and cutting costs. His forward thinking gained the attention of his general manager, who promoted McKnight to cost accountant. Within two years of his first promotion, McKnight was offered his first opportunity in a leadership position when he was placed in charge of 3M’s Chicago office. McKnight’s next promotion came in 1914 when, at the age of 27, he moved to St. Paul and took over as the general manager at 3M’s headquarter office. It would only take McKnight two short years before he advanced to 3M’s vice president at the age of 29 in 1916. In 1929, McKnight, at the age of 42, took over for Edgar Ober as president of the company as the latter became too ill to carry on.

Under McKnight’s management, 3M went from a struggling mineral processing company to a multinational technology manufacturing company. The company began manufacturing sandpaper in 1921, and masking tape and the now-famous “Scotch Tape” in 1925. These products stabilized the company. In 1947, 3M began processing chemicals, allowing it to expand its business to Canada, Mexico, and Europe.

McKnight would hold the position of president for 20 years until 1949, when he was appointed chairman of the board. He held that position until 1966, at which point he was relieved and given the title of honorary chairman of the board until 1972. During his career

with 3M, McKnight was recognized as having saved the company from the brink of bankruptcy and turning it into a multinational corporation with his emphasis on research and development and employee innovation.

McKnight also created the McKnight Foundation with his wife, Maude L. McKnight, in 1953 in Minneapolis, Minnesota. The McKnight Foundation has no ties to the 3M Company. McKnight spent 59 years working for his private philanthropic organization, running it alongside his wife until shortly after her death, at which point he passed on its leadership to Virginia McKnight, their only child. Under her guidance, the foundation began offering community grants in Minnesota and still does so today.

William L. McKnight's hobbies included Thoroughbred horse racing; he owned Tartan Farm, a breeding center in Ocala, Florida. McKnight owned the award-winning horses Dr. Patches, Ta Wee, Dr. Fager, and the horse Intentionally, who won the Futurity Stakes by setting a track record time. McKnight's horses are known for winning the Eclipse award.

On March 4, 1978, William L. McKnight died at age 90. Seventeen years after his death, the Junior Achievement U.S. Business inducted McKnight into their hall of fame for businessmen. McKnight was recognized for his contribution to changing the culture of corporations by emphasizing that management should delegate tasks and encourage employee imitative and innovation; many of his contributions to business are still in practice today at 3M.

Joshua McPhail

See also Scotch Tape

Further Reading

- Comfort, Mildred. 2011. *William L. McKnight, Industrialist: A Biographical Sketch of the Chairman of the Board, Minnesota Mining and Manufacturing Company*. New York: Literary Licensing.
- Gundling, Ernest. 2000. *The 3M Way to Innovation: Balancing People and Profit*. Tokyo: Kodansha.
- Mattox, John. 2016. *Learning Analytics: Measurement Innovations to Support Employee Development*. New York: Kogan Page.

Mercury Vapor Lamp. See Hewitt, Peter C.

Midgley, Thomas (1889–1944)

American inventor and chemist Thomas Midgley is best known for inventing leaded gasoline and chlorofluorocarbons (CFCs).

Born in Beaver Falls, Pennsylvania, in 1889, Midgley spent his childhood in Columbus, Ohio. After graduating from Cornell University in 1911, Midgley worked briefly at National Cash Register (NCR), where he met the inventor and entrepreneur Charles Kettering. Midgley worked in his family business before going to work at Kettering's Dayton Engineering in 1916.

Kettering assigned Midgley to solve the problem of "knock," a tendency of early combustion engines to begin shaking violently at high power. Part of this was due to early piston design, and part was due to the low-octane gasoline available at the time. Midgley experimented with various fuel additives before discovering tetraethyl lead in 1921.

From the beginning, Midgley and other researchers were concerned about the effects that lead would have on the public. Midgley was hospitalized for lead poisoning shortly before leaded gasoline was first offered for sale on February 1, 1923, and six workers producing tetraethyl lead died of lead poisoning the following year. Public outcry and a 1925 hearing led by the U.S. surgeon general raised awareness, but General Motors and other corporate interests quashed concerns over the harmful effects of leaded gasoline. Leaded gasoline allowed the development of more powerful engines and larger vehicles, although catalytic refining techniques developed a decade later would eventually allow high-octane fuels to replace leaded gasoline.

In 1928, Kettering took charge of GM's research department and assigned Midgley to solve the problem of refrigerants. Within a day, Midgley and his assistants deduced that a fluorine compound would meet the requirements of a refrigerant (which had to expand quickly from a liquid to a gas, absorbing heat from the surrounding area) without the toxicity problems of ammonia and other common refrigerants. By

the end of the day, they had begun testing on chlorofluorocarbons (CFCs). The compound R-12 (later called Freon) was unveiled in 1930, and by the decade's end, it was in worldwide use in air-conditioners and refrigerators. CFCs later became popular industrial solvents and cleaners; this is how much of the CFC in the atmosphere escaped.

Midgley began researching synthetic rubber, but his research slowed dramatically after he came down with polio in 1940. He was paralyzed from the waist down. In 1944, he was elected president of the American Chemical Society; shortly afterward, he either was accidentally strangled in the ropes that allowed him to move around his bedroom or committed suicide.

Midgley's inventions made a dramatic difference in the world, for good—his fuel additives jump-started the development of airplanes and automobiles, and Freon saved countless people from food poisoning or spoiled medicines—and for bad, because the additives were toxic to the environment and humans. Midgley died before the discovery in the 1970s that CFCs were destroying the ozone layer and before the revelations of health problems that led to the 1986 ban on leaded gasoline in the United States.

James L. Erwin

See also Kettering, Charles F.; *Vol. 3, Sec. 1: Chlorofluorocarbons (CFCs)*

Further Reading

McGrayne, Sharon Bertsch. 2001. *Prometheans in the Lab: Chemistry and the Making of the Modern World*. New York: McGraw-Hill.

Midgley, Thomas. 2001. *From the Periodic Table to Production: The Life of Thomas Midgley, Jr.* Corona, CA: Stargazer.

Morgan, Garrett (1877–1963)

Garrett Morgan invented the a hair straightener, a safety hood that later inspired a similar device used in World War I, and an improved traffic signal that increased safety on American roadways.

Garrett Morgan was born on March 4, 1877, in Paris, Kentucky. His mother was Elizabeth Reed

Morgan, who was half Native American, and he was half African American. His father was Sydney Morgan, a former slave that was freed in 1863. With only an elementary school education, Morgan moved to Cincinnati, Ohio, at age 14 to find a job. He became a handyman for a landowner. In 1895, he moved to Cleveland, where he started work as a sewing machine repairman. In 1907, he opened his own repair shop business. A year later, he married Mary Anne Hassek and had three sons.

In 1909, Morgan and his wife opened a tailoring shop. While working at his shop, Morgan developed his first invention: hair-straightening gel. Morgan noticed that sewing machine needles would leave scorch marks on fabrics because of friction. He experimented with some chemical solutions and created a solution that reduced the friction. He tested this solution on his own hair and found that it stood up straight. He had just stumbled upon the first hair straightener. Morgan then established the G. A. Morgan Hair Refining Company to sell his product in 1913.

After witnessing a traffic accident at an intersection involving an automobile and a horse wagon, Morgan received a patent for an improved traffic signal from the U.S. Patent Office on November 20, 1923. At the time, there were only stop and go signals in the United States. Morgan's upgraded traffic signal consisted of a T-shaped pole with an additional signal: a yield sign. He had created a warning signal that would tell cars that they needed to slow to a stop. It was an equivalent of the yellow light in today's traffic light. This sign stopped traffic from all directions to let pedestrians cross. This important improvement decreased the number of car accidents at intersections and increased the safety of drivers and pedestrians. He eventually sold his patent to General Electric for \$40,000.

In 1914, Morgan invented a breathing device called the "safety hood." Morgan was inspired to make a breathing device because he had witnessed firefighters struggling to breathe in the overwhelming amount of smoke and gas present at fires. The safety hood uses a sponge that is soaked in water, which helps filter out the smoke and cools breathable air as it enters a tube. This device made breathing safer for people exposed

to smoke, gases, and other toxins. His safety hoods were successfully adopted in the Northern United States, but he faced resistance and skepticism in the South, most likely due to his race. However, Morgan was able to demonstrate his invention on July 24, 1916, when a tunnel in Lake Erie collapsed because of a natural gas explosion. Morgan and his brother, Frank, rushed to the scene with several safety hoods. Many of the rescuers were doubtful that Morgan's device would work; however, he proved them wrong. He, his brother, and several volunteer rescuers put on hoods and went into the tunnel. They successfully rescued two men. Because of this incident, the South was more receptive to his invention. Unfortunately, Cleveland officials ignored Morgan's act of heroism and credited other rescuers for their bravery.

In 1917, a group of Cleveland citizens awarded Morgan with a gold medal, thanking him for saving those men in the Lake Erie explosion. Morgan's safety hood became widely used by firefighters. Morgan sold his safety hood to the U.S. Navy, and eventually, the army used it to develop gas masks that were used in World War I. Soon, Morgan's inventions started to gain popularity in North America and England, and demand for them skyrocketed. Morgan later died on July 27, 1963, at age 86.

Tracy Liu

See also Traffic Light, Electric; *Vol. 2, Sec. 1*: Carver, George Washington; *Vol. 2, Sec. 3*: Gas Mask

Further Reading

- Holmes, Keith C. 2008. *Black Inventors: Crafting over 200 Years of Success*. Brooklyn, NY: Global Black Inventor Research Projects.
- Murphy, Patricia J. 2004. *Garrett Morgan: Inventor of the Traffic Light and Gas Mask*. Berkeley Heights, NJ: Enslow.

Motorcycle (Pre–World War II)

The motorcycle originated from the safety bicycle, which has front and rear wheels of the same size and utilizes a pedal crank around the rear wheel. The general concept of the motorcycle was conceived

simultaneously across Europe by various engineers and inventors. The original motorcycle was steam powered and referred to as the “velocipede.” The production of the motorcycle was greatly impacted by World War I's need for effective frontline communication. This helped to launch the Harley-Davidson Motor Company, founded by William Harley and Arthur Davidson, as one of the world's most successful motorcycle companies.

One of the first motorcycles created in the 1860s and originally named the velocipede was created by Pierre Michaux in Paris. This design reached the United States in 1863 via an employee of Michaux. Next came the Roper steam velocipede, built by Sylvester Roper in Boston, Massachusetts. There is debate whether Michaux's or Roper's velocipedes are truly the world's first motorcycles. The first petroleum-fueled, internal combustion motorcycle was the Daimler Reitwagen, designed by German inventors in 1885. It was unlike other bicycles at the time and did not use the principles of bicycle or motorcycle dynamics. The Butler Petrol Cycle, built by the Merryweather Fire Engine Company, was created in 1888 by Edward Butler. It was a three-wheeled gas-powered vehicle and contained a flat, twin four-stroke engine that used water cooling and rotary valves. In 1894, the Hildebrand & Wolfmüller was created, and it was the world's first production motorcycle. Its patent protected a two-cylinder four-stroke engine with a bore and stroke of 90 by 117 millimeters. It could propel a weight of 50 kilograms and had a maximum speed of 45 kilometers an hour. The engine was located on the floor of the frame between its wheels and used hot tube ignition as well as a ventilated tube heater.

In 1898, Triumph, a British motorcycle manufacturing company, shifted its focus from automobiles to motorcycles. It produced its first motorcycle in 1902 fitted with a Belgian-built engine: the model H. Its rear wheel was driven by a belt, and it used an air-cooled, four-stroke, single-cylinder engine. The model H is commonly regarded as the first “modern motorcycle.” The Indian Motorcycle Manufacturing Company, founded by two bicycle racers, created the diamond-framed Indian Single design in 1901. It made 20,000 bikes a year until 1913. Before the war effort, the race to produce motorcycles was inspired by a new



This 1914 photo of the Butte Motorcycle Club demonstrates the popularity of the motorized bicycle, or motorcycle in the early 20th century. (Library of Congress)

machine-based sport that replace the “obsolete” manually pedaled bicycle. Harley-Davidson started to produce its motorcycles in 1903.

In 1917, the United States government purchased over 20,000 motorcycles from Harley Davidson and Triumph for use in World War I. The motorcycles provided effective communications with frontline troops, replacing horses with dispatch riders on motorcycles who carried messages, did reconnaissance, and acted as military police. These first motorcycles included the Triumph Model H.

William Harley was an American engineer and businessman as well as the cofounder of Harley-Davidson Motor Company. Harley was born in Milwaukee, Wisconsin, in 1880 to immigrant parents. At the age of 15, he worked in the Meiselbach bicycle factory, where he drafted plans for an engine to be mounted on a bicycle. Harley received a degree in mechanical engineering from the University of Wisconsin-Madison in 1907. He served as chief engineer and treasurer at Harley-Davidson until his death in 1943.

Arthur Davidson was an American businessman and was one of the original founders of Harley-Davidson. Davidson was born in Milwaukee, Wisconsin,

and was of Scottish descent. In 1903, he went into business with his childhood friend William Harley. Together they built motorcycles in his family’s shed. During World Wars I and II, Harley-Davidson diverted motorcycle production to help outfit soldiers for the war efforts. This was rewarded with troops trained and willing to buy their product, as well as the U.S. government purchasing a surplus exclusively of Harley-Davidson brand motorcycles.

Today the motorcycle is a common means of transportation. Its fuel economy is far superior to that of automobiles, but it sacrifices the safety of an enclosed vehicle. The use of motorcycles today also varies from bikes built for sport as well as bikes built for leisure, like “cruisers.”

Thomas A. Newton

See also Automobile Technologies (Pre–World War II); *Vol. 2, Sec. 3: Military Technology (World War II)*; *Vol. 3, Sec. 1: Automotive Technologies (Post–World War II)*

Further Reading

Ambrose, Tom. 2013. *A History of Cycling in Fifty Bikes: From the Velocipede to the Pinarello, the*

Bicycles That Have Shaped the World. Emmaus, PA: Rodale Books.

Siegal, Margie. 2014. *Harley-Davidson: A History of the World's Most Famous Motorcycle.* (Shire Library USA.) London: Shire.

Movies. See Talking Movies

National Advisory Committee for Aeronautics (NACA)

The National Advisory Committee for Aeronautics (NACA) is an agency of the U.S. federal government for practicing and promoting aeronautic research. The NACA was established in 1915 and was transformed into the National Aeronautics and Space Administration (NASA) in 1958 in response to the Cold War space race.

Two years before the United States entered World War I, the federal government passed legislation to establish an agency that would coordinate war-related science. When the legislation came before Congress in 1913, it failed, but in 1915, with war looming, the proposal was passed by both houses and signed into law by President Woodrow Wilson. Franklin D. Roosevelt, who was at that time assistant secretary of the navy, endorsed the plans for NACA.

The initial budget of \$5,000 per year limited NACA's influence. President Wilson asked airplane innovators Wilbur and Orville Wright to join the organization in the hopes that they could help promote commercial and military aviation. The organization grew quickly. By 1922, NACA employed over 100 people and by 1938, there were over 400 at four facilities: Langley Aeronautical Laboratory in Virginia, Ames Aeronautical Laboratory at Moffett Field in Northern California, Lewis Research Center in Ohio, and Muroc Flight Test Unit at Edwards Air Force Base in Southern California.

NACA did considerable research with wind tunnels, the first of which it built at Langley. Wind tunnel research helped engineers and scientists better understand aerodynamics and was used to test new airplane and wing designs.

During World War II, NACA pioneered aircraft development, including the game-changing P-51 Mustang. Made by American Aviation, the P-51 was a fighter plane with a considerably longer range than previous fighters. This allowed the plane to accompany bombers farther into enemy territory so the bombers were not left unprotected in the face of enemy fighter airplanes.

In the post–World War II era, NACA focused on supersonic research like that for the NACA X-1, an early rocket-powered aircraft that became the Bell X-1. Key to NACA research was the “area rule” that that determines operating speeds for supersonic aircraft.

In 1958, President Dwight D. Eisenhower oversaw the transformation of NACA to NASA on the principle that the nation needed less military technology development and more peaceful, civilian space science.

Peg A. Lamphier

See also *Vol. 2, Sec. 1:* Wright, Wilbur and Orville; *Vol. 2, Sec. 3:* B-17 Flying Fortress; Curtiss-Wright Aeronautical Engineering Cadettes; Helicopter; Women's Airforce Service Pilots (WASPs); *Vol. 3, Sec. 1:* National Aeronautics and Space Administration (NASA)

Further Reading

- Bilstein, Roger E., and Frank Walter Anderson. 1989. *Orders of Magnitude: A History of the NACA and NASA, 1915–1990.* Washington, D.C.: National Aeronautics and Space Administration, Office of Management, Scientific and Technical Information Division.
- Dawson, Virginia P. 1991. *Engines and Innovation: Lewis Laboratory and American Propulsion Technology.* Washington, D.C.: National Aeronautics and Space Administration, Office of Management, Scientific and Technical Information Division.
- Roland, Alex. 1985. *Model Research: The National Advisory Committee for Aeronautics, 1915–1958.* Washington, D.C.: Scientific and Technical Information Branch, National Aeronautics and Space Administration.

Noether, Amalie Emmy (1882–1935)

The algebra theorems of world-renowned Jewish mathematician Amalie Emmy Noether have garnered her the nickname “the Mother of Modern Algebra.” She also made notable contributions to theoretical physics, authoring Noether’s theorem. An émigrée from Nazi Germany, Noether worked at Bryn Mawr College in Pennsylvania, where she taught and researched during the height of her career. Albert Einstein said that she was the most important woman in the history of mathematics.

Noether was born in 1882 to Max and Ida Amalia Noether in southeastern Germany. Max studied mathematics at the University of Heidelberg, where he served as a faculty member for a few years before transferring to the University of Erlangen in 1888. Although Noether spent her childhood education following subjects traditionally studied by young girls, she chose to pursue mathematics as an adult.

In 1900, Noether began attending classes at the University of Erlangen. She furthered her education for a semester at the University of Göttingen in 1903, where she met Hermann Minkowski, Otto Blumenthal, Felix Klein, and David Hilbert, all noted mathematicians. After returning to the University of Erlangen, Noether graduated in 1907 and became the second woman in the school’s history to receive a doctorate. Upon graduating, she worked as a professor without monetary compensation before returning to teach in Göttingen in 1915.

Noether continued to work without pay for years, living in poverty. She considered her work as an educator and mathematician to be a civil service in line with her socialist ideals. When she was paid for her work, she only received a small salary, barely enough to support herself. After World War I, Noether faced discrimination under the Third Reich; despite losing her job as a professor, she continued to reach out to her students to discuss mathematics and their future plans. As her leftist views became more apparent to her students, many of whom leaned toward the right and toward Nazi fascism, they began to resist learning from her. The complaints against her led to her eviction from her home.

Under Nazi Germany’s Law for the Restoration of the Professional Civil Service, many instructors, including Noether, had their teaching licenses revoked for

being Jewish or politically left leaning, under the premise that anyone who did not support right-wing fascist politics was disloyal to Germany. It was clear that due to her cultural heritage and political beliefs, which included pacifism, Noether was not welcome in Germany.

In light of the policies under the Third Reich, many universities in the United States offered refuge for German academics. For example, Albert Einstein and Hermann Weyl, both admirers of Noether’s work and personality, worked at Princeton’s Institute for Advanced Study. In 1933, the American all-women’s college Bryn Mawr expressed interest in giving Noether a position as a professor of mathematics. Noether accepted the offer and immigrated to the United States.

It was at Bryn Mawr that Noether found a strong support network in the mathematics community. She worked with Anna Wheeler, an American mathematician and pioneer in functional analysis. Wheeler and Noether shared a common experience in that they both knew how difficult it was for a woman to be accepted as a serious mathematician. By the 1930s, Wheeler had found acceptance as a full professor and head of the math department at Bryn Mawr; she had spent years being rejected for teaching posts in favor of male mathematicians. While at Bryn Mawr under Wheeler’s wing, Noether developed two of the most crucial theorems (Noether’s theorem and Noether’s second theorem) in modern abstract algebra. Her contributions to mathematic research would also serve as a major influence in the field of theoretical physics. During her career, she published over 40 articles on algebraic math, which were marked by her imaginative thinking. Although Noether was invited to lecture at Princeton, where Albert Einstein taught after emigrating from Germany, the all-female Bryn Mawr remained her academic home.

Noether’s health began to decline in 1935, when doctors discovered an ovarian cyst. After her surgery, Noether developed a high fever and died suddenly. Her funeral was held at Bryn Mawr, and many of her colleagues in her field, such as Hermann Weyl and Richard Bauer, attended. Her ashes are interred at the M. Carey Thomas Library.

Cynthia M. Zavala

See also *Vol. 2, Sec. 1*: Richards, Ellen Swallow

Further Reading

- Neuenschwander, Dwight E. 2010. *Emmy Noether's Wonderful Theorem*. New York: Johns Hopkins University Press.
- Tent, M. B. W. 2008. *Emmy Noether: The Mother of Modern Algebra*. Wellesley: A. K. Peters/CRC Press.

Olds, Ransom Eli (1864–1950)

Advertising pitches put millions of Americans behind the wheels of cars with model names like Cutlass, Eighty-Eight, Ninety-Eight, and Toronado. But while these model names are memorable, the name of their make is just as unforgettable: Oldsmobile, named after its creator, Ransom Eli Olds.

Born in Ohio, the youngest son of a father who was a blacksmith and a mother who crafted patterns for a living, Ransom Olds and his family eventually moved to Lansing, Michigan, where he started the Olds Motor Vehicle Company in 1897. The 33-year-old carmaker needed a partner, so copper tycoon Samuel Smith entered the business, and it was renamed Olds Motor Works in 1899. Ransom was named vice president and general manager. By 1901, Olds produced 11 prototypes capable of running on steam, electricity, or gasoline. Of the 11, it was decided to enter a sporty little runabout, the Oldsmobile Curved Dash, in that year's New York Automobile Show. The Curved Dash didn't win any awards, but sales of the car more than made up for any disappointment. With a sticker price of about \$650, it was America's first mass-produced compact car. Olds introduced a stationary assembly line, the first of its kind in the automobile industry. The innovation enabled him to increase his factory's output. Nearly 19,000 Curved Dash cars were sold before the model was discontinued in 1905.

The Curved Dash wasn't all that was being discontinued by Olds Motor Works. The company's namesake was also heading for the exit. Ransom Olds's partnership with the Smith family had become contentious, and tensions escalated when Samuel Smith's son Fred joined the company. Olds and the younger Smith clashed frequently, and in 1904, Olds was dismissed as vice president and general manager. He left the company that same year. General Motors

purchased Olds Motor Works in 1908 and discontinued the Oldsmobile line in 2004.

Olds may have been finished with the Olds Motor Works, but not with cars. He resurfaced as the head of the R. E. Olds Motor Car Company until the threat of a lawsuit from his former partners forced him to change the name. It was then called the REO Motor Car Company, using the initials of Olds's name as an acronym. This simple move kept Ransom Olds out of court and in the car and truck business as REO's president and chairman until 1925. Olds's new company manufactured the REO Speed Wagon, ancestor to the modern pickup truck, from 1919 through the 1950s. A popular 20th-century rock 'n' roll band named itself after the vehicle.

Olds was also an early automobile racing enthusiast. He competed in Florida races in the 1890s and 1910s, in the process innovating racing automobile design. In 1946, Ransom Olds was inducted into the Automotive Hall of Fame. Olds died in Lansing, Michigan, in 1950.

John A. Morello

See also Automobile Technologies (Pre–World War II); General Motors (GM)

Further Reading

- May, George S. 1977. *R. E. Olds: Auto Industry Pioneer*. Grand Rapids, MI: Eerdmans.

Panama Canal

The Panama Canal, a man-made waterway that connects the Atlantic and Pacific Oceans through the Isthmus of Panama, has a long history. Spain, France, and other countries saw the benefits of a canal there but were unable to make it a reality. Although the United States had to overcome many obstacles, it was eventually able to secure the rights to build the canal, an engineering marvel. Since 2000, when the canal was returned to Panamanian control, it faced problems and world competition.

After Christopher Columbus (1451–1506) completed his first voyage across the Atlantic Ocean and landed in America in 1492, Spain began a massive exploration project of the New World. Columbus himself made several other voyages to the Americas, but he

failed to find a water passage through the two American continents. In 1513, Vasco Núñez de Balboa (1475–1519) was the first European explorer to cross the Isthmus of Panama and see the Pacific Ocean. Seven years later, Ferdinand Magellan (1480–1521) found an ocean passage from the Atlantic to the Pacific Ocean through the lower tip of South America, which came to be known as the Strait of Magellan. In fact, Magellan named the ocean *Mar Pacifico* (peaceful ocean), as his ship survived the tumultuous strait waters and entered the calm waters of the earth's largest ocean in 1520.

The Spanish king Charles V (1500–1558) was the first leader to come up with the idea of constructing a canal across the Isthmus of Panama. Charles V realized that the conquest of Peru, Ecuador, and Asia would be greatly facilitated by a water route through the American continents. In 1534, the king ordered a survey for a Panamanian canal project, but he was forced to abandon the project due to war in Europe. Three hundred years later, the revolutionary Simón Bolívar (1783–1830) hired a British engineer to conduct a study of the Panamanian landscape to determine whether a canal across the isthmus was possible. The engineer produced a positive report, but Bolívar died the next year.

The 13,000-mile (20,900 km) journey that U.S. merchant ships were forced to take from New York to the lower tip of South America and then to San Francisco took months to complete. However, the ability to cut through Panama would reduce the trip to 5,200 miles (8,370 km) and shorten the time by more than half. The tremendous savings in fuel costs and time would greatly benefit American industry. In the mid-1830s, President Andrew Jackson (1767–1845) sent an American negotiator to Bogotá, the capital of Colombia, to try and secure the rights to build a U.S. road across Panama (then a province of Colombia). The plan was to use horse-drawn carriages on the U.S. road to transport merchandise to ships docked at Atlantic and Pacific Ocean ports. Negotiations were going well until a similar Dutch deal in Nicaragua failed. When Jackson heard the news of the failure, he lost interest in the road project.

In the late 1840s, British and American ambassadors negotiated the Clayton-Bulwer Treaty (1850), a partnership between the two nations to build infrastructure in Panama to facilitate transport through the isthmus. The 40-year British-American partnership in Panama

produced railroads but no canal. However, Colombian leaders still longed for a canal through Panama, which they believed would be a big money-making enterprise.

In 1880, the Frenchman Ferdinand de Lesseps (1805–1894), who had gained fame as the builder of the Suez Canal in Egypt, secured a concession from the Colombian government to build a canal in Panama. However, the French venture (1881–1887) failed, because de Lesseps made at least three major mistakes. In his planning, he had failed to factor in the climate of the region, which is much different from the dry Egyptian climate. In Panama, the humid and rainy weather caused mudslides that buried months of excavation. Also, as he had done in Egypt, he insisted on digging a sea-level canal from ocean to ocean. Due to many miles of rocky terrain, however, the task was technologically impossible to accomplish, even by equipment invented more than a century later. Last, he failed to address the problem of disease. Yellow fever, malaria, and other tropical diseases claimed the lives of about 20,000 of his workers.

Having dug less than a third of the way through Panama and spent almost \$300 million, the French enterprise went bankrupt in 1887. Investors in the French company wanted to recover some of their losses. Consequently, in 1889, the French government appointed a liquidation firm, which placed the French company up for sale at a price of \$109 million.

By then, much of the work the company had accomplished had been buried by mudslides. Most of the equipment was worn and rusty. The only real thing of value that the French company held was the concession for the right to build the canal granted by Colombia. However, it was set to expire in a few years, so France urgently needed to sell it, and the United States seemed the most likely buyer. U.S. leaders were, in fact, still interested in building a canal through Central America.

The Spanish American War (1898) between the United States and Spain in the Caribbean had left little doubt about the military strategic importance of a Central American canal. President William McKinley (1843–1901) appointed a Canal Commission to investigate the entire region and report its findings. In 1901, the report stated that a canal through Nicaragua would be the cheapest option. McKinley embraced the recommendation, and the House of Representatives passed a bill to dig in Nicaragua. Before the U.S.

Senate could cast a deciding vote, the French company lowered its price to \$40 million. The Canal Commission switched its recommendation of the canal location to Panama. After McKinley's assassination in 1901, President Theodore Roosevelt (1858–1919) supported the Panama Canal initiative.

In 1901, the first issue that Roosevelt had to address was to negotiate a breakup of the British-American partnership in Panama, which had been established by the Clayton-Bulwer Treaty half a century before. Roosevelt sent Secretary of State John Hay (1838–1905) to secure a new agreement with the British. Hay fulfilled the task that same year. Next, Roosevelt ordered Hay to negotiate terms with Colombia. According to the treaty that Hay and Colombian representatives signed in 1903, Colombia granted the United States the right to build a canal zone six miles wide through Panama. In return, the United States agreed to pay Colombia \$10 million and then annual lease payments of \$250,000 for nine years after the initial payment. The treaty also stated that the lease would be renewable in perpetuity.

The U.S. Senate approved the treaty that same year. However, influential Colombian leaders rejected the terms. After they expressed their disapproval of the treaty, the Colombian congress unanimously rejected it. Roosevelt was furious. Late that year, Panamanians launched a one-day rebellion against Colombia. The rebels formed a government and ratified a constitution. The presence of the USS *Nashville* discouraged a Colombian military response. With one recorded death, the Republic of Panama was established, and the United States immediately extended diplomatic recognition of the new nation.

The Hay-Bunau-Varilla Treaty signed by Panama and the United States contained almost identical terms to the treaty that had previously been negotiated with Colombia. Most important to the United States, the treaty gave it the right to build, run, maintain, and protect a canal through Panama. The swiftness with which the Hay-Bunau-Varilla Treaty was negotiated had a lot to do with Roosevelt's promise that American canal interests in Panama obligated American support for Panama's continued independence. Roosevelt boasted that he had taken the canal zone while Congress continued to debate over it until 1904. Under the circumstances, Congress had little choice but to secure the last remaining rights to the canal by paying the French

company (New Panama Canal Company) its asking price of \$40 million.

Roosevelt became the first president to leave the continental United States while in office. During his visit to the canal zone, he oversaw the work, operated a crane, and encouraged the workers to make the "dust fly." Roosevelt was determined to succeed where the French had failed. He was convinced that success with the canal would prove American technological superiority to the world. He concurrently built up the U.S. Navy and showed it off by sending it on a world tour. Years later, while reflecting on his presidential career, he ranked his role in the Panama Canal as one of his greatest achievements.

However, before the canal could be built, Americans would need to address the same problems that had plagued the French venture 20 years earlier: mudslides, determining the best construction plan, and diseases. By providing viable answers to these problems, the crews created an engineering marvel. To minimize the possibility of mudslides, American engineers ordered crews to cut the canal using wider angles than the French had done, and the new strategy required American crews to excavate four times as much earth. During the entire project, approximately 96 million cubic yards of dirt were excavated, which was enough to pave a road from Earth to the moon. The wider excavation also resulted in a wider canal than had been originally planned.

The second, and closely related, issue was to determine the best construction plan. The French had attempted a sea-level design that had proven disastrous. In contrast, American engineers developed a design with locked chambers that would raise and lower ships as they traveled through the Panamanian landscape. On the Atlantic Ocean side, three locks raised ships 240 feet to the level of a lake. On the Pacific Ocean side, two locks lowered the ships to sea level again. Each of the five locked chambers contained four walls that were 1,200 feet long. Each one of those walls was built using more cement than the then-tallest building in the world. To raise and lower ships, water entered and exited the locked chambers through 15-foot-wide holes. Giant electrical generators powered the gates of each lock, and a railroad-like locomotive towed ships through the locks.

Yet none of these great accomplishments would have been possible if the problem of disease had not

been dealt with. Dr. William C. Gorgas (1854–1920), a military doctor who had been successful in conquering yellow fever in Cuba was sent to Panama in 1906. Gorgas believed that the most effective way to eliminate yellow fever and malaria was by preventing mosquitoes from hatching. In a rainy environment with innumerable pockets of water, his task was formidable. With only seven paid helpers and many volunteers, his team swept through the area emptying all containers of rainwater, spraying a mixture of oil and insecticide, sealing rooms with nets, and isolating infected people. Within a few months, Gorgas was successful in greatly reducing the threat of tropical disease in the canal zone. The canal was completed in 1914, 10 years after construction had begun.

For many years, the canal benefited world trade tremendously by slashing travel times and costs. For example, freighters from East Asia had entered the Gulf of Mexico in 41 days before the use of the canal. In contrast, the same ships reached their destination in 25 days by crossing through the canal. In the 1970s, President Jimmy Carter signed a treaty to return the canal to Panama in 2000. Since that time, the canal

faced the danger of becoming obsolete, as many cargo ships were built too large to fit through the canal. In 2007, Panamanian leaders began a \$5.25 billion expansion project, which added another, deeper lane with larger locks for larger ships.

In 2015, Egyptian leaders announced the expansion of the Suez Canal to cut down on wait times, and a Chinese entrepreneur announced plans to build a canal through Nicaragua.

Rolando Avila

See also Vol. 2, Sec. 3: Hoover Dam

Further Reading

Leonard, Thomas M. 1993. *Panama, the Canal, and the United States: A Guide to Issues and References*. Claremont, CA: Regina Books.

McCullough, David. 1977. *The Path Between the Seas: The Creation of the Panama Canal*. New York: Simon & Schuster.

Vick, Karl. 2015. "The Grand Canal." *Time*, May 25, 32–36.

Primary Document: Excerpt from President Theodore Roosevelt's Message to Congress After Returning from the Canal Zone in Panama (1906)

In December 1906, President Theodore Roosevelt addressed Congress to inform it of the progress being made at the Canal Zone in Panama. Roosevelt had good reason to know—he had visited the Panamanian Isthmus in November. As a result of his investigation, he announced that he would restructure the Isthmian Canal Commission to make the project more efficient. The following is an excerpt of Roosevelt's address to Congress.

December 17, 1906

To the Senate and House of Representatives:

I came to the conclusion that, speaking generally, there was no warrant for complaint about the food. Doubtless it grows monotonous after awhile. Any man accustomed to handling large masses of men knows that some of them, even though otherwise very good men, are sure to grumble about something, and usually about their food. Schoolboys,

college boys, and boarders in boarding houses make similar complaints; so do soldiers and sailors. On this very trip, on one of the warships, a seaman came to complain to the second watch officer about the quality of the cocoa at the seaman's mess, saying that it was not sweet enough; it was pointed out to him that there was sugar on the table and he could always put it in, to which he responded that that was the cook's business and not his. I think that the complaint as to the food on the Isthmus has but little more foundation than that of the sailor in question. Moreover, I was given to understand that one real cause of complaint was that at the government hotels no liquor is served, and some of the drinking men, therefore, refused to go to them. The number of men using the government hotels is steadily increasing.

Of the nineteen or twenty thousand day laborers employed on the canal, a few hundred are Spaniards. These do excellent work. Their foreman told me that

they did twice as well as the West India laborers. They keep healthy and no difficulty is experienced with them in any way. Some Italian laborers are also employed in connection with the drilling. As might be expected, with labor as high priced as at present in the United States, it has not so far proved practicable to get any ordinary laborers from the United States. The American wage-workers on the Isthmus are the highly-paid skilled mechanics of the types mentioned previously. A steady effort is being made to secure Italians, and especially to procure more Spaniards, because of the very satisfactory results that have come from their employment; and their numbers will be increased as far as possible. It has not proved possible, however, to get them in anything like the numbers needed for the work, and from present appearances we shall in the main have to rely, for the ordinary unskilled work, partly upon colored laborers from the West Indies, partly upon Chinese labor. It certainly ought to be unnecessary to point out that the American workingman in the United States has no concern whatever in the question as to whether the rough work on the Isthmus, which is performed by aliens in any event, is done by aliens from one country with a black skin or by aliens from another country with a yellow skin. Our business is to dig the canal as efficiently and as quickly as possible; provided always that nothing is done that is inhumane to any laborers, and nothing that interferes with the wages of or lowers the standard of living of our own workmen. Having in view this principle, I have arranged to try several thousand Chinese laborers. This is desirable both because we must try to find out what laborers are most efficient, and, furthermore, because we should not leave ourselves at the mercy of any one type of foreign labor. At present the great bulk of the unskilled labor on the Isthmus is done by West India negroes, chiefly from Jamaica, Barbados, and the other English possessions. One of the governors of the lands in question has shown an unfriendly disposition to our work, and has thrown obstacles in the way of our getting the labor needed; and it is highly undesirable to give any outsiders the impression, however ill-founded, that they are indispensable and can dictate terms to us.

The West India laborers are fairly, but only fairly, satisfactory. Some of the men do very well indeed; the better class, who are to be found as foremen, as

skilled mechanics, as policemen, are good men; and many of the ordinary day laborers are also good. But thousands of those who are brought over under contract (at our expense) go off into the jungle to live, or loaf around Colon, or work so badly after the first three or four days as to cause a serious diminution of the amount of labor performed on Friday and Saturday of each week. I questioned many of these Jamaica laborers as to the conditions of their work and what, if any, changes they wished. I received many complaints from them, but as regards most of these complaints they themselves contradicted one another. In all cases where the complaint was as to their treatment by any individual it proved, on examination, that this individual was himself a West India man of color, either a policeman, a storekeeper, or an assistant storekeeper. Doubtless there must be many complaints against Americans; but those to whom I spoke did not happen to make any such complaint to me. There was no complaint of the housing; I saw but one set of quarters for colored laborers which I thought poor, and this was in an old French house. The barracks for unmarried men are roomy, well ventilated, and clean, with canvas bunks for each man, and a kind of false attic at the top, where the trunks and other belongings of the different men are kept. The clothes are hung on clotheslines, nothing being allowed to be kept on the floor. In each of these big rooms there were tables and lamps, and usually a few books or papers, and in almost every room there was a Bible; the books being the property of the laborers themselves. The cleanliness of the quarters is secured by daily inspection. The quarters for the married negro laborers were good. They were neatly kept, and in almost every case the men living in them, whose wives or daughters did the cooking for them, were far better satisfied and of a higher grade than the ordinary bachelor negroes. Not only were the quarters in which these negro laborers were living much superior to those in which I am informed they live at home, but they were much superior to the huts to be seen in the jungles of Panama itself, beside the railroad tracks, in which the lower class of native Panamans live, as well as the negro workmen when they leave the employ of the canal and go into the jungles. A single glance at the two sets of buildings is enough to show the great superiority in point of comfort, cleanliness, and healthfulness of the

Government houses as compared with the native houses.

The negroes generally do their own cooking, the bachelors cooking in sheds provided by the Government and using their own pots. In the different camps there was a wide variation in the character of these cooking sheds. In some, where the camps were completed, the kitchen or cooking sheds, as well as the bathrooms and water-closets, were all in excellent trim, while there were board sidewalks leading from building to building. In other camps the kitchens or cook sheds had not been floored, and the sidewalks had not been put down, while in one camp the bath houses were not yet up. In each case, however, every effort was being made to hurry on the construction, and I do not believe that the delays had been greater than were inevitable in such work. The laborers are accustomed to do their own cooking; but there was much complaint, especially among the bachelors, as to the quantity, and some as to the quality, of the food they got from the commissary department, especially as regards yams. On the other hand, the married men and their wives, and the more advanced among the bachelors, almost invariably expressed themselves as entirely satisfied with their treatment at the commissary stores; except that they stated that they generally could not get yams there, and had to purchase them outside. The chief complaint was that the prices were too high. It is unavoidable that the prices should be higher than in their own homes; and after careful investigation I came to the conclusion that the chief trouble lay in the fact that the yams, plantains, and the like are rather perishable food, and are very bulky compared to the amount of nourishment they contain, so that it is costly to import them in large quantities and difficult to keep them. Nevertheless, I felt that an effort should be made to secure them a more ample supply of their favorite food, and so directed; and I believe that ultimately the Government must itself feed them. I am having this matter looked into.

The superintendent having immediate charge of one gang of men at the Colon reservoir stated that he endeavored to get them to substitute beans and other nourishing food for the stringy, watery yams, because the men keep their strength and health better on the more nourishing food. Inasmuch, however, as they are accustomed to yams it is difficult to get them to

eat the more strengthening food, and some time elapses before they grow accustomed to it. At this reservoir there has been a curious experience. It is off in the jungle by itself at the end of a couple of miles of a little toy railroad. In order to get the laborers there, they were given free food (and of course free lodgings); and yet it proved difficult to keep them, because they wished to be where they could reach the dramshop and places of amusement.

I was struck by the superior comfort and respectability of the lives of the married men. It would, in my opinion, be a most admirable thing if a much larger number of the men had their wives, for with their advent all complaints about the food and cooking are almost sure to cease.

I had an interview with Mr. Mallet, the British consul, to find out if there was any just cause for complaint as to the treatment of the West India negroes. He informed me most emphatically that there was not, and authorized me to give his statement publicity. He said that not only was the condition of the laborers far better than had been the case under the old French Company, but that year by year the condition was improving under our own regime. He stated that complaints were continually brought to him, and that he always investigated them; and that for the last six months he had failed to find a single complaint of a serious nature that contained any justification whatever.

One of the greatest needs at present is to provide amusements both for the white men and the black. The Young Men's Christian Association is trying to do good work and should be in every way encouraged. But the Government should do the main work. I have specifically called the attention of the Commission to this matter, and something has been accomplished already. Anything done for the welfare of the men adds to their efficiency and money devoted to that purpose is, therefore, properly to be considered as spent in building the canal. It is imperatively necessary to provide ample recreation and amusement if the men are to be kept well and healthy. I call the special attention of Congress to this need.

This gathering, distributing, and caring for the great force of laborers is one of the giant features of the work. That friction will from time to time occur in connection therewith is inevitable. The astonishing

thing is that the work has been performed so well and that the machinery runs so smoothly. From my own experience I am able to say that more care had been exercised in housing, feeding, and generally paying heed to the needs of the skilled mechanics and ordinary laborers in the work on this canal than is the case in the construction of new railroads or in any other similar private or public work in the United States proper; and it is the testimony of all people competent to speak that on no other similar work anywhere in the Tropics—indeed, as far as I know, anywhere else—has there been such forethought and such success achieved in providing for the needs of the men who do the work.

I have now dealt with the hygienic conditions which make it possible to employ a great force of laborers, and with the task of gathering, housing, and feeding these laborers. There remains to consider the actual work which has to be done; the work because of which these laborers are gathered together—the work of constructing the canal. This is under the direct control of the Chief Engineer, Mr. Stevens, who has already shown admirable results, and whom we can safely trust to achieve similar results in the future.

Our people found on the Isthmus a certain amount of old French material and equipment which could be used. Some of it, in addition, could be sold as scrap iron. Some could be used for furnishing the foundation for filling in. For much no possible use could be devised that would not cost more than it would bring in.

The work is now going on with a vigor and efficiency pleasant to witness. The three big problems of the canal are the La Boca dams, the Gatun dam, and the Culebra cut. The Culebra cut must be made, anyhow; but of course changes as to the dams, or at least as to the locks adjacent to the dams, may still occur. The La Boca dams offer no particular problem, the bottom material being so good that there is a practical certainty, not merely as to what can be achieved, but as to the time of achievement. The Gatun dam offers the most serious problem which we have to solve; and yet the ablest men on the Isthmus believe that this problem is certain of solution along the lines proposed; although, of course, it necessitates great toil, energy, and intelligence, and although equally,

of course, there will be some little risk in connection with the work. The risk arises from the fact that some of the material near the bottom is not so good as could be desired. If the huge earth dam now contemplated is thrown across from one foothill to the other we will have what is practically a low, broad, mountain ridge behind which will rise the inland lake. This artificial mountain will probably show less seepage, that is, will have greater restraining capacity than the average natural mountain range. The exact locality of the locks at this dam—as at the other dams—is now being determined. In April next Secretary Taft, with three of the ablest engineers of the country—Messrs. Noble, Stearns, and Ripley—will visit the Isthmus, and the three engineers will make the final and conclusive examinations as to the exact site for each lock. Meanwhile the work is going ahead without a break.

The Culebra cut does not offer such great risks: that is, the damage liable to occur from occasional land slips will not represent what may be called major disasters. The work will merely call for intelligence, perseverance, and executive capacity. It is, however, the work upon which most labor will have to be spent. The dams will be composed of the earth taken out of the cut and very possibly the building of the locks and dams will take even longer than the cutting in Culebra itself.

The main work is now being done in the Culebra cut. It was striking and impressive to see the huge steam shovels in full play, the dumping trains carrying away the rock and earth they dislodged. The implements of French excavating machinery, which often stand a little way from the line of work, though of excellent construction, look like the veriest toys when compared with these new steam shovels, just as the French dumping cars seem like toy cars when compared with the long trains of huge cars, dumped by steam plows, which are now in use. This represents the enormous advance that has been made in machinery during the past quarter of a century. No doubt a quarter of a century hence this new machinery, of which we are now so proud, will similarly seem out of date, but it is certainly serving its purpose well now. The old French cars had to be entirely discarded. We still have in use a few of the more modern, but not most modern, cars, which hold but

twelve yards of earth. They can be employed on certain lines with sharp curves. But the recent cars hold from twenty-five to thirty yards apiece, and instead of the old clumsy methods of unloading them, a steam plow is drawn from end to end of the whole vestibuled train, thus immensely economizing labor. In the rainy season the steam shovels can do but little in dirt, but they work steadily in rock and in the

harder ground. There were some twenty-five at work during the time I was on the Isthmus, and their tremendous power and efficiency were most impressive.

Source: Roosevelt, Theodore. 1910. "Message to Congress After Returning from the Canal Zone in Panama," December 17, 1906. *Presidential Addresses and State Papers*. Volume V. New York: The Review of Reviews.

Pennington, Mary Engle (1872–1952)

Bacteriological chemist and refrigeration engineer Mary Engle Pennington is most famous for advancements in refrigeration technology. She was also the first female lab chief at the U.S. Food and Drug Administration. The advancements she made were spurred by her involvement in the effort during World War I to improve refrigeration of perishable food sent to overseas troops.

Pennington was born in Nashville, Tennessee, on October 8, 1872. Her family moved to Philadelphia; Pennington attended the Towne Scientific School there, where she completed the required courses for a degree in chemistry and minors in botany and zoology in 1892. The university did not grant degrees to women, so she received a certificate of achievement for her studies. In 1895, she earned her PhD from the University of Pennsylvania, one of the few universities at the time to grant degrees to women.

Upon graduation, Pennington was unable to find employment. She formed her own laboratory group in Philadelphia before finding a job at the Philadelphia Bureau of Health, where, as a bacteriologist, she worked on improving sanitation standards for the handling of dairy products. In 1905, she went to work for the U.S. Department of Agriculture (USDA) as a bacteriological chemist. There, she set standards for the safe processing of chickens raised for human consumption. Two years later, she became the chief of the USDA's new Food Research Laboratory. Her then boss, Harvey Wiley, had put her name up for the job, disguising the fact that she was a woman by using her initials on the job application. Once the ruse was discovered, Wiley defended Pennington's hiring, arguing

that no federal law prevented women's employment in the USDA.

In the 1910s, she headed a team of researchers to improve the functioning of refrigerated railroad cars, with the aim of making food safer for World War I soldiers. The advancements and research conducted at the Food Research Laboratory during the war led to interest in the entire process of storing and transporting perishable food. In 1923, Pennington founded the Household Refrigeration Bureau to bring awareness to the public on safe practices in domestic refrigeration. In addition, she had support from the National Association of Ice Industries to produce and distribute pamphlets on home food safety.

Ultimately, Pennington's work aided in keeping a low bacterial count in refrigerated foods that were critical to food safety and purity. In efforts to refine and improve food preservation techniques, Pennington suggested the preservation of food through freezing at a time when practices such as smoking and canning dominated the industry.

The American Chemical Society gave Pennington the Garvin-Olin Medal for achievements in chemistry. She is also a 2002 inductee of the Women's National Hall of Fame.

Omar Pelcastre

See also *Vol. 2, Sec. 1*: Food Preservation; *Vol. 2, Sec. 3*: Freeze-Dried Food; Refrigerator

Further Reading

Shearer, Benjamin F., and Barbara S. Shearer, eds. *Notable Women in the Physical Sciences: A Biographical Dictionary*. Westport, CT: Greenwood Press, 1997.

Petroleum Industry (Pre–World War II)

Modern society has become increasingly reliant on oil. The widespread use of cars and plastic has turned what used to be a relatively mundane resource into something vital for the world that we live in today. However, it was during the 19th century that oil became the modern necessity that American society relies upon.

All throughout human history, oil was used in one way or another. Many cultures around the world used it for waterproofing wooden ships. There were also other practical and medicinal uses of oil in some societies, such as records from 1298 of Marco Polo describing it being burned to provide light, or Francisco Ariosto writing about oil from springs being used as a medicine. In 1625, Johan Volck wrote a paper exploring possible uses for the oil found in the Pechelbronn district of Alsace, but he found no financial backers for his proposed experiments. Oil was used in various cultures but not industrialized or extracted on a wide scale until quite late in history, and it was not yet a viable general energy source.

More modern uses of oil appeared in the first half of the 1800s. The large-scale machinery that industrialization brought required frequent lubrication to prevent wear and breakage, and while many oils and lubricants were based on animal products, others made use of petroleum oil from within the earth.

In 1853, kerosene was first distilled by Ignacy Łukasiewicz. Not long after that, more commodities would be developed using oil, and all around the world, oil industries began to spring up in several countries. As the world industrialized, more and more of it developed a craving for oil, and this demand made its extraction a profitable venture; it was thus commercialized. Several prominent developers laid their claims on oil reserves all around the world—notably the Seneca Oil Company of New Haven, Connecticut, and the Virginia Petroleum Company. This pattern occurred across the world, with oil reserves being claimed in Russia under the orders of the czar. Soon, oil was carried to major cities for refinement and processing.

In the 1800s, more oil was discovered, claimed, and drilled for. The United States developed a large

oil industry, and the oil companies consolidated their power, dominated by the trusts—several companies merging to create a monopoly on one particular resource. So, in the United States, oil was placed in the hands of relatively few owners. By the 1900s, with the acquisition of the Pacific Oil company, Standard Oil would control over 90 percent of oil refining within the United States—practically the only source of refined oil in the country. With its domination of what was quickly becoming a vital resource, the industrial giant obtained great political power.

The trust became the target of various smear campaigns at the beginning of the 20th century. Public opinion was beginning to turn against the notion of monopolies, because they had complete control over prices in specific markets. Standard Oil was not immune to antitrust campaigns and eventually, government policy turned against it. In 1911, the U.S. Supreme Court finally broke up the oil trust into smaller companies to encourage competition.

By this point, oil had risen in importance in modern society and become an important strategic resource the world over. With the increasing industrialization of the European nations, Britain had converted its entire navy from coal to oil power by 1905. The beginning of the 20th century brought major discoveries of oil in the Middle East. Companies set themselves up to establish control over Middle Eastern oil. Over the next several years, oil was discovered in various colonies of the world's superpowers. While the United States had its own domestic oil reserves, increased demand continued to drive American foreign policy.

The superpowers clashed in 1914 with the beginning of World War I. Like many other resources, oil became essential in the war effort, especially for fueling aircraft and land vehicles for the military. Even with the United States' late entry into the war, the development of industry and military buildup ensured that even an isolationist United States would continue to increase its demand for oil.

After World War I, the tank and other vehicles would replace many of the military roles that horses had previously played. The modernization of armies meant replacing the horse with the automobile. This

trend spilled over into the civilian sector as the horse was replaced with the car, and older coal- and steam-driven train engines would be steadily replaced with newer, diesel-powered trains.

The demand for oil escalated in the United States after World War I. In 1923, Edward Doheny's Pan American Petroleum and Transport Company tapped large oil reserves in Alaska. New methods were being developed to refine oil in the 1920s, such as the gravity method and the seismic method, allowing for more types of deposits to be extracted.

In this era, several of the oil companies that we are familiar with today began to form, including Standard Oil of Indiana, which became Amoco, and Standard Oil of New York, which became Mobil. In 1932, the discovery of oil in California saw Standard Oil of California, the company that would later become Chevron, grow and prosper.

In 1930, U.S. oil prices collapsed. The discovery of the East Texas oil fields suddenly flooded the market with new supplies of U.S. oil. This required a regulatory commission to be founded to properly regulate oil production in Texas and help to stabilize the market after this economic disaster. These efforts would not be fruitful until 1931, when, despite resistance from the oil producers themselves and several legal battles, regulatory commissions helped to establish some order in this chaotic new discovery.

U.S. oil companies also secured oil rights in South America, Saudi Arabia, Eastern Europe, and other international locations. International ventures frequently merged with U.S. companies, and through this, the United States gained international economic influence. Oil productions increased into the millions of barrels per day for a single company.

In the late 1800s, oil became a valuable resource even before the invention and widespread adoption of oil products as fuel. As the automobile and other vehicles switched from coal to diesel, militaries the world over were some of the first to adopt oil as fuel on a wide scale, skyrocketing demand. This prompted the development of oil extraction, refinement, and technology tools. While before World War II, there might not have been a car in every garage, industrial and commercial tasks were being fueled by oil. What at

one time was seen as a specialty product quickly grew into the necessary resource we know it as today. This era laid the foundations of oil as humanity's primary method of energy generation, and events such as World War I began to introduce the world to the automobile, airplane, and other vehicles that replaced horses.

Rosanne Welch

See also Automobile Technologies (Pre–World War II); *Vol. 1, Sec. 2*: Internal Combustion Engine; *Vol. 3, Sec. 2*: Solar Energy; Wind Energy

Further Reading

- Kanwar, Ranvir Singh. 2000. "States, Firms, and Oil: British Policy, 1939–54." Thesis, University of Warwick.
- Sabin, Paul. 2004. *Crude Politics—the California Oil Market, 1900–1940*. Berkeley: University of California Press.
- Vassiliou, M. S. 2009. *The A to Z of the Petroleum Industry*. Lanham, MD: Scarecrow.

Pop-Up Toaster

Early toasters browned bread on one side at a time, and they required constant supervision to prevent burning the bread. In 1919, Charles Strite invented the first automatic pop-up toaster for restaurant use. His patent was granted in 1921, and the toaster was produced by the Waters Genter Company.

Strite's "Toastmaster" could brown bread on both sides simultaneously, turn off the heating element, and eject the toast when ready. It contained a series of four levers and buttons. The timing lever wound up the spring motor that operated the timing mechanism. The toast lever lowered the bread into the toaster and turned on the electric current. As the timing lever rose, it approached the top of the toaster until it tripped an automatic shutoff that broke the current and released the toast lever, thus removing the toasted bread from the heat source.

The directions for the toaster cautioned users about the ideal consistency and thickness of the bread slices to be toasted. Sales of the Toastmaster were



This 1921 toastmaster was the first home use pop-up toaster. It could brown bread on both sides simultaneously and eject the toasted bread when the variable timer went off. (Tara Walton/Toronto Star via Getty Images)

greatly increased when the Continental Baking Company began selling presliced Wonder Bread.

Lynda C. Titterington

See also *Vol. 1, Sec. 2: Coffee Percolator*

Further Reading

Molotch, Harvey. 2003. *Where Stuff Comes From: How Toasters, Toilets, Cars, Computers, and Many Other Things Came to Be as They Are*. New York: Routledge.

Rubin, Susan G. 1998. *Toilets, Toasters & Telephones: The How and Why of Everyday Objects*. San Diego: HMH Books for Young Readers.

Snodgrass, Mary Ellen. 2004. *Encyclopedia of Kitchen History*. New York: Routledge.

Pushpin

The pushpin was an invention by Edwin Moore, an inventor from Newark, New Jersey. In 1899, he filed a patent for a pin with a handle that allowed people to stick papers and others notes to a corkboard.

The intent of the original design of the pin was for the user to stick it into something easily, for whatever it was coated with to be resistant to corrosion, and for it to be cheaply mass-produced.

The patent also included the idea of modification and decoration on the top of the pin for purely aesthetic reasons. The patent gave the example of the top of the pin being replaced with a decorative pig's head made from molded or fabricated celluloid.

After the patent was accepted, Moore began to produce pushpins himself. After a large order from the Eastman Kodak Company, sales of Moore's pins began to be successful. The Moore Push-Pin Company still exists today, operating out of Wyndmoor, Pennsylvania.

Jordan Ciccarelli

See also Vol. 2, Sec. 1: Paper Clip

Further Reading

Bellis, Mary. 2006. "The Invention of the Push Pin." *The Inventors*. <http://theinventors.org/library/weekly/aa103000a.htm>, accessed August 29, 2018.

Moore, Edwin. 1899. Push-Pin. U.S. Patent 654,319, filed October 20, 1933, and issued February 19, 1935.

Radio

Radio technology utilizes electromagnetic radiation (radio waves) to transmit and receive information. Many scientists contributed to the development of radio. Based on telegraph technology, radio evolved from a primitive, one-to-one short-distance wireless transmission system to a long-distance, digital, satellite-powered network capable of delivering a signal to a wide area.

The radio industry had a tremendous cultural influence on daily life. Even though radio's Golden Age was eclipsed by the advent of television, the radio industry remained relevant. The constant growth of the industry led to government regulation. Ongoing innovations in radio technology have resulted in new applications, discoveries, and opportunities.

The Italian Guglielmo Marconi (1874–1937) has traditionally been regarded as the "Father of Radio"; however, many people contributed to the development of radio technology. In fact, single-wire telegraph technology, invented and patented by Samuel Morse (1791–1872) in 1844, served as the basis for radio technology. In the late 1800s, British scientist James Clerk Maxwell (1831–1879) and German scientist Heinrich Hertz (1857–1894) were

the first to theorize and verify through experimentation the existence of wireless electromagnetic waves.

Based on these developments, in 1894, British scientist Oliver Lodge (1851–1940) developed equipment capable of sending and receiving a weak wireless electromagnetic Morse code signal (of a few dots and dashes) across a maximum distance of 55 meters. Although still in the prototype stage, Lodge's achievement was a great leap forward in the historical development of radio. During the next few years, scientists in Italy, France, Russia, and Brazil successfully duplicated Lodge's feat.

Marconi was the first to send and receive wireless telegraph messages across much wider distances by transmitting from tall masts and bouncing signals off the ionosphere (a layer of the earth's atmosphere) and over the horizon. After receiving a patent for his invention in 1896, Marconi demonstrated it to the world by transmitting across the English Channel (1899) and the Atlantic Ocean (1901). Marconi envisioned radio ideally as a means of one-to-one (private) contact between merchant ships and the armed forces.

Based on Marconi's success in telegraphy (the process for sending and receiving wireless telegraph messages), in 1902, Danish scientist Valdemar Poulsen (1869–1942) introduced telephony (the process for sending and receiving sound) by modulating the electromagnetic signal into a continuous wave. In 1906, Canadian Reginald Fessenden (1866–1932) successfully broadcasted voices and music across the Massachusetts coastline. Several other scientists were responsible for developments in radio equipment (including the diode and dynamic speakers) that made it possible to amplify radio signals and send them to wider audiences, but Fessenden's accomplishment was most responsible for introducing the possibility that radio technology could go beyond Marconi's original limited vision.

Although radio was, in fact, used as Marconi had envisioned, after World War I (1914–1918), it was also more popularly used as a means for mass communication and entertainment. For example, with a focus on passenger safety, in 1910 the

U.S. Congress passed the Wireless Ship Act, which required that all oceangoing passenger ships be equipped with a radio and a radio operator. Also, during World War I, the military used radio technology as a vital communication tool. However, by 1922, the number of privately owned and operated radio stations with an emphasis on consumer culture had increased dramatically in both Britain (150) and the United States (500).

Through experimentation, scientists discovered the limits of the radio spectrum. They found that its lower end is not suited for communication, because the data rate decreases as frequency decreases. On the other hand, at the higher end of the radio spectrum, signals fail to bounce back to earth and are instead absorbed into the atmosphere. Consequently, after government officials were made aware that the radio spectrum was finite real estate, they took steps to regulate it in the face of a booming radio industry. President Calvin Coolidge signed the Radio Act of 1927, which established the Federal Radio Commission (FRC).

In 1934, the FRC was replaced by the Federal Communications Commission (FCC), which took steps to allocate and monitor the use of the radio spectrum for nongovernment entities. In addition, both the FCC and the National Association of Broadcasters issued a code of ethics for radio programming and advertising. The codes (or rules) were intended to ensure that radio broadcasters served the public interest in a fair and trustworthy manner. However, the codes, which forbade indecency, obscenity, and the use of profanity, created an ongoing tension between rule makers and free-speech proponents who viewed the enforcement of the broadcasting rules as censorship. In more recent years, regulators have given satellite, cable, and Internet radio broadcasters much more freedom of expression.

During the 1920s, the radio was one of the most popular household appliances. By 1933, two-thirds of all homes in the United States had radios (twice the number of homes with telephones). The radio transformed daily life, and it brought the family together. After dinner, millions of families gathered around the radio and listened to a variety of programs,

including music, sporting events, soap operas, comedy shows, worship services, weather forecasts, and newscasts on national and world events. In short, the radio connected people to the outside world like never before.

Beginning with President Calvin Coolidge (1872–1933), presidents utilized the radio to address the nation. In fact, during the Great Depression (1929–1939) and World War II (1939–1945), President Franklin Delano Roosevelt (1882–1945) used the radio to deliver his monthly “fireside chats,” which gave millions of Americans hope. Beginning in 1922, radio advertising promoted consumer culture—the sale of a variety of consumer goods, including food, household appliances, soap, and automobiles. Radio music broadcasts also influenced music fads. For example, jazz, as well as country and western music, which had been popular in isolated regions of the nation, exploded on the national stage in the 1920s due to radio airplay. The phenomenon reoccurred with rock ‘n’ roll music and the rise of popular artists like Elvis Presley in the mid-1950s. In fact, the tremendous influence of radio remained unmatched for almost half a century until it was eclipsed by television in the late 1950s.

As had been the case during World War I, during World War II, the military used the radio as an indispensable communication tool. However, the World War II era produced many more innovations in radio technology. Two of the most significant advances included the mobile radio transmitter and receiver (that was operable during land, air, and sea transport) and radar (used to locate enemy submarines so they could be destroyed).

Although the supremacy of radio in daily life was dashed by television, radio remained an important fixture in the world. For example, between 1945 and 1960 (before a significant number of man-made satellites orbited the earth), many television stations used microwave radio technology to enable them to boost their signals so that they could broadcast nationally. One reason that radio fostered a growing audience after the advent of television was that transistor radios were much more portable and cheaper than televisions. As television transitioned from black-and-white

programming to color in an attempt to capture more viewers, radio evolved to include stereo frequency modulation (FM) alongside mono amplitude modulation (AM).

There were 2,300 radio stations in the United States in 1972. By 1976, the number had grown to 3,700—so rapidly that Congress created the National Telecommunications and Information Administration (NTIA) in 1978 to reassess and reallocate frequencies within the spectrum and to reduce the possibility of radio interference between allocated stations.

In the 1980s and 1990s, NTIA regulation of radio grew in importance as the spectrum continued to grow crowded with both private and public radio stations. In the mid-1990s, some European radio stations began offering higher-fidelity sound than FM by broadcasting digital recordings in a digital format. Within a few years, American stations began adopting the digital audio broadcasting (DAB) format. Besides the advantage of better sound quality, digital signals could be compressed, which resulted in more room for stations within the spectrum. Besides profits generated by radio stations, technological advancements in radio technology encouraged the growth of the radio industry.

By 2000, there were more than 12,000 stations in the United States broadcasting with the aid of satellite networks. By 2001, there were 13,000 American stations that reached 95 percent of all consumers every week. Another rising star in the radio industry was Internet radio. By 2000, numerous Internet radio stations offered streaming personalized digital content. Advancements in radio technology led to new uses. Today, cordless telephones and wireless streaming audio and video feeds use low-powered radio transmitters and receivers. In like manner, cellular telephones use wireless radio technology to connect to distant phone lines. Satellite radio providers beam digital radio content down to earth, where subscribers with special receivers decode radio signals.

Some groups became alarmed by the proliferation of devices (such as mobile cellular phones, wireless Internet connections, radars, and radio and television transmitters) that were constantly bombarding the

human body with radio waves. Although the topic remained controversial, some believed that sufficient intensity and/or duration of exposure to electromagnetic radiation could harm humans, resulting in various illnesses including chronic headaches, insomnia, depression, and cancer. While experiments showed that extremely high levels of radio waves could cause tissue damage, most radio wave intensity (emitted from cellular phone base stations and television transmitting stations) were typically thousands of times lower than radio wave intensity emitted by devices close to the body. In addition, scientists were unable to find a direct link between radio waves and any specific illness.

The National Environmental Policy Act of 1969 required the FCC to regulate consumer exposure to radio waves. In 1996, the FCC set the maximum permissible exposure limits for field strength and power density for transmitters operating at frequencies of 300 kHz to 100 GHz. In addition, the FCC set specific absorption rate (SAR) limits for devices operating within close proximity to the body, which manufacturers had to comply with. Various consumer support groups issued guidelines that people could follow to reduce exposure.

Radio technology also offers humanity an opportunity to better understand the universe. In 1932, Karl Jansky (1905–1950) discovered radio noise in the Milky Way galaxy. The discovery led to the establishment of radio astronomy. The radio telescope is an astronomical instrument consisting of a radio receiver and an antenna system that is used to detect radio frequency radiation emitted by extraterrestrial sources. Today, there are hundreds of ground-based radio telescopes all around the world as well as space-based radio telescopes. Radio telescopes inside the solar system have given us a much better understanding of planet orbit patterns and the imaging of asteroids.

Beyond the solar system, the use of radio telescopes has led to the discovery of different kinds of pulsars. In general terms, the use of radio telescopes has given scientists the ability to observe the universe in new ways that would otherwise not be possible. Radio telescopes also offer hope for discoveries that have not yet been made. For example,

since the 1960s, several groups of scientists, including those who created the most well known program, the Search for Extra Terrestrial Intelligence (SETI), pointed radio telescopes into space with the intent of locating extraterrestrial radio signals. However, the scant years of searching for radio waves, which travel at the speed of light, have not yet led to the discovery of alien signals in a vast and expanding universe that is more than 27 billion light-years wide.

Rolando Avila

See also Triode Tube; *Vol. 1, Sec. 3*: Morse, Samuel F. B.; Morse Code; Telegraph; *Vol. 2, Sec. 3*: FM Radio; Lamarr, Hedy; Radar; Television; *Vol. 3, Sec. 1*:

Satellites and Space Probes; Transistor Radio; *Vol. 3, Sec. 3*: Smartphone and 3G Network

Further Reading

- American Radio Relay League. 2006. *The ARRL Handbook for Radio Communications*, 2007. Newington, CT: American Radio Relay League.
- Keith, Michael C. 2000. *Talking Radio: An Oral History of American Radio in the Television Age*. Armonk, NY: M. E. Sharpe.
- Someda, Carlo G. 2006. *Electromagnetic Waves*. 2nd ed. Boca Raton, FL: CRC.
- Sterling, Christopher H., and John Michael Kittross. 2002. *Stay Tuned: A History of American Broadcasting*. 3rd ed. Mahwah, NJ: Lawrence Erlbaum.

Primary Document: “Radio’s Real Uses” by E. E. Free, Science Editor for *The Forum* (1926)

The 1920s saw significant anxiety about the new technology that was the radio. New York governor Al Smith proclaimed the radio useless in national politics because it was only good for facts and no good for making appeals to passion. The science editor for a national magazine, The Forum, thought differently.

Radio broadcasting is spectacular and amusing but virtually useless. It is difficult to make out a convincing case for the value of listening to the material now served out by the American broadcasters. Even if the quality of this material be improved, as it undoubtedly will be, one must still question whether the home amusement thus so easily provided will sufficiently raise the level of public culture to be worth what it costs in time and money and the diversion of human effort. It is quite possible to argue, indeed, that the very ease with which information or what-not reaches one by radio makes it just so much the less valuable. In educational matters, as in commerce, men usually value things by what they cost. Culture painlessly acquired is likely to be lost as painlessly—and as promptly. Is the whole radio excitement to result, then, in nothing but a further debauching [morally corrupting] of the American

mind in the direction of still lazier cravings for sensationalism? I believe not. There are at least two directions, quite different ones, in which radio has already proved its utility and its right to survive. One of these is its practical service as a means of communication. The other is its effect, continually growing more evident, in stimulating the revival of that exceedingly useful and desirable creature, the amateur scientist.

I had not, up to that time, thought of it [radio] as a sort of mental hypodermic [injection]. I had, as a matter of fact, connected it principally with the national defense, and I remember that originally I had some vague notion about the service the radio would render in times of war, in the matter of expediting [sending] messages, detecting spies, etc. Of course I knew that it was a Tremendous Contribution—to what or to whom I was not exactly sure, but I had heard it styled so by ministers in the pulpit, and I was sure that in time it would be included in school histories under the chapter entitled Benefits of Inventions and Discoveries, which explained how much the cotton gin, the locomotive, the telephone, and the motion picture had done for civilization. By actual contact, however, both as a listener and as a broadcaster, I learned that the radio was associated

with that other form of service which is a sort of national rallying cry in America, "Service," with a capital S, that intangible something, which the merchant professes to confer upon you in addition to the goods for which you pay; Its programs were free. You could tune in anywhere without even giving a tithe to the government. As one station sang nightly: Just set your dial And stay a while With W-X-Y-Z. There it is, up in the air, absolutely free, waiting for you to pull it down with the aid of electricity. Opera and symphonic music, jazz, twenty minutes of good reading, how to cook by Auntie Jane, tales for the kiddies and prayers set to music, even "Now I lay me

down to sleep"; sermons and exhortations not to drink, gamble, and blaspheme, with music by the white-robed choir; advice on how to spread your income by investment brokers; advice on how to make your shoes last longer by shoe salesmen; talks by the mayor on civic duty, on "Your Boy" by the master of the Boy Scouts; on the right sort of boys by the head of the Y.M.C.A., and the right sort of girls by the head of the Y.W.C.A.; barn dances, recitals of music schools, whole acts of plays, speeches, speeches, speeches.

Source: Free, E. E. "Radio's Real Uses" *The Forum*, March 1926.

Rocky Mountain Laboratories

The Rocky Mountain Laboratories (RML) was established in 1928. The facility is a biosafety 4 laboratory. Researchers at the RML pioneered research into Rocky Mountain spotted fever.

In the late 19th and early 20th centuries, the Western United States were plagued with a disease called "black measles." Now known as Rocky Mountain spotted fever, the disease often proved fatal. Montana's newly formed State Board of Health began investigating the disease in 1901. Researchers set up camp in the Bitterroot Valley of western Montana, working from log cabins and canvas tents. In 1906, Howard Ricketts proved that the disease was communicated by tick bite, contrary to local legend, which held that one contracted the disease from drinking snowmelt. In 1910, Ricketts left the facility to study typhus in Mexico City. He contracted typhus and died. In honor of his contributions the organism that causes Rocky Mountain spotted fever is named *Rickettsia rickettsii*.

In 1910, Clarence Birdseye joined the research facility as a tick collector as part of his work for the U.S. Biological Survey. Montana instituted a tick eradication program that made some headway against the disease. In 1927, the Montana state legislature approved funding for Rocky Mountain Labs in Hamilton to study ticks and Rocky Mountain spotted fever. Hamilton residents opposed the new lab, arguing that ticks

would escape the facility and infect locals. Thus, a moat was built around the facility, based on the fact that ticks cannot swim. The new facility employed 4 professional researchers and 22 support staff personnel.

In 1937, the RML became part of the National Institute of Health. The laboratory worked on vaccines for typhus and yellow fever during World War II, both diseases that plagued soldiers worldwide.

In the 21st century, the RML continues to lead disease research. The facility functions as a maximum containment laboratory working on chronic wasting disease, Q fever, chlamydia, Lyme disease, tularemia, influenza, and much more.

Peg A. Lamphier

See also Bell Telephone Laboratories; Birdseye, Clarence

Further Reading

Harden, Victoria. 1990. *Rocky Mountain Spotted Fever: History of a Twentieth-Century Disease*. Baltimore: John Hopkins University Press.

Safety Razor

Before the 1900s, men all over the world struggled to find a safe and easy way to shave off facial hair. King Camp Gillette patented an improved safety razor in 1904 that revolutionized body hair removal.

Before the invention of the safety razor, men used a variety of methods to remove facial hair. As early as 30,000 BC, they used clamshells for this. By 3000 BC, ancient Egyptians used copper razors, and in 1500 BC, bronze razors appeared in Scandinavia.

In the 1600s, steel-edged straight razors, sometimes called “cutthroat razors,” appeared in England. In 1770, a French barber named Jean-Jacques Perret invented a single-blade razor with a folding wooden handle that functioned as a guard. This became the razor of choice for men until the 20th century.

Gillette did not invent the safety razor. German American brothers Frederick and Otto Kampfe patented a forged-blade safety razor in 1875. But forged blades dulled after use and were expensive.

King Gillette determined to change men’s shaving experience by designing a safe and disposable razor. Gillette faced a few problems. First, he couldn’t find a way to construct razor blades thin enough. Second, because he couldn’t develop the blades for his disposable razor, he couldn’t find any investors to support his product.

Machinist William Emery Nickerson, who was also Gillette’s partner, solved the problem by designing a machine that could manufacture thin blades. He also changed the razor’s handle design. From that innovation, the Gillette brand flourished. Although their endeavors were a success, they still had a bit of trouble convincing the rest of the world that disposable razor blades were as effective as the traditional straight razor blades.

Gillette marketed the razors using what is now called the “razor and blade business model.” They sold their razors at a steeply discounted price and then made money from selling consumers the blades that went into them. This model, where an item is sold cheaply and a complementary item is sold for higher prices, became an industry standard for a number of consumer products, including printers and ink cartridges, video game consoles and games, and more.

The safety razor blade continues to evolve. What started out as a metal razor with one blade is now available in an assortment of razors with multiple blades. Many razors have plastic handles and are

disposable in their entirety (rather than just the blade being disposable).

Emma E. L. Burke

See also Vol. 2, Sec. 1: Curling Iron; Jockstrap

Further Reading

Adams, Russell B. 1878. *King C. Gillette, The Man and His Wonderful Shaving Device*. Boston: Little, Brown.

Scotch Tape

“Scotch tape” is both a brand name and common use name for transparent tape. Richard Drew invented Scotch tape while working for 3M Company in Minnesota in 1925.

Before inventing Scotch tape, Drew invented masking tape. Two-tone paint jobs were popular automobile paint schemes in the 1920s, and Drew learned that it was difficult for auto painters to create a clean border between two paint colors. In 1922, he developed a two-inch-wide, paper-backed, pressure-sensitive strip that had adhesive along its edges but not in the center. The tape did not stick well, causing an auto painter to suggest that the “Scotch bosses” at 3M use more adhesive—“Scotch” being a slang word for “cheap.”

In 1925, Drew invented the first transparent tape, then called Sellotape.

Drew’s tape used a cellophane, rather than paper, backing. Tape made by 3M and many other companies sold well during the Great Depression because it was an affordable way for people to repair everyday objects that they could not afford to replace. Today, transparent tape is commonly used worldwide in households, classrooms, and places of business.

Emma E. L. Burke

See also Vol. 2, Sec. 1: Office Technology (Pre–World War II); Tape Measure

Further Reading

Gundling, Ernest. 2000. *The 3M Way to Innovation: Balancing People and Profit*. Tokyo: Kodansha American.

Subway System of New York City

New York's subway system is of immense importance to the city's economy, environment, and culture. This innovation helped tame New York's increasingly congested population. The subway system was primarily designed and built as electrically powered transit in 1904, and it is still the same today. Today, the amount of electricity it takes to power the subways annually is about 1.8 billion kilowatt-hours. Four million people travel through the subway per day, and it currently provides 20,000 jobs.

Between 1850 and 1900, the New York population increased fivefold. Steam locomotives were carrying 115 million passengers in 1886, twice the entire population of the United States at the time. Apartments were extremely crowded; there was no running water, no light, or much privacy. Worst of all, filth plagued the city, and the poor were stuffed into tenements, where they developed deadly epidemics like yellow fever, tuberculosis, cholera, and typhus. The solution seemed clear: an urban mass transit system to disperse the population to other areas of the city and alleviate the clogged environment.

The first elevated railway to transport passengers opened in 1870. In the beginning, elevated railways were propelled by moving cables, a system considered deficient later on when they switched over to steam locomotives. The problem was, steam power contributed to the unsanitary living conditions of the city. Soot from coal polluted the skies, and beyond that, the system was extremely loud. Eventually, a multiple control unit, designed and created by engineer Frank Sprague, gave each car its own power unit. This invention changed the way that elevated railways traveled, and it paved the way for the first underground urban mass transit in New York City.

The first subway in New York was designed and created by humanist Alfred Ely Beach. In 1870, he successfully built a pneumatic subway system 312 feet long. Not only was this transit propelled by air, it had a grand piano on board. Many religious people disagreed with the idea of travel being underground and therefore closer to hell. The reason this isn't the current subway system that New York uses is that before Beach could finally gain the approval of politicians

and the public to expand the subway, the stock market turned for the worse and crashed in 1873.

Twenty-one years later, Mayor Abram S. Hewitt passed the Rapid Transit Act of 1894, which finally authorized the development of a municipal subway system. John B. McDonald was a contractor hired by the city as a private entrepreneur to build the subway. The idea proposed was that the city would own the underground railway as well as finance the construction, and it would charge rent. An independent company would operate the subway and therefore keep the profits. However, McDonald faced the problem of raising enough capital to finance the operation. August Belmont, heir to a giant fortune, partnered with McDonald and formed the company still known today as the Interborough Rapid Transit. Their unyielding determination built the subway in four years.

Although four years is rather expedient for such an immense project, there were some roadblocks in the development. William Barclay Parsons, a young chief engineer, was in charge of the design of the tunnels and oversaw its construction. The "cut and cover" technique, which consisted of digging shallow holes and staying near the surface, was applied in the construction of the tunnels. So, basically, workers broke through pavement, dug tunnels, and covered them again.

A huge problem that Parsons encountered was the previous existence of sewer, gas, and water mains that needed to be diverted. There were also issues with the unpredictability of the soil, as it could turn out to be quicksand or solid rock that proved difficult to handle. The use of dynamite, the method used for destroying rock, would disturb the peace by scaring horses and shattering glass windows above. Shoring up and protecting existing construction was also another stressor for Parsons.

The inauguration of New York's subway system finally came on October 27, 1904. The line was a single-track loop under the City Hall. With four tracks, local and express services were provided. The line went from north of the Brooklyn Bridge to Center Street, Elm Street, Lafayette Place, 4th Avenue, Park Avenue, and East 42nd Street. Under 42nd Street, the subway line turned at Times Square and up north under Broadway. The operation was a complete win for the city and only five cents a ride.

Shortly after the inauguration, the city's overcrowding began to vex the subways. They needed to expand—but instead of financing more construction, Belmont took over existing elevated railways, like the Manhattan Railway in 1903 and the Metropolitan Street Railway Company in 1906. In 1913, Dual Contracts was created to start new subway construction. It was decided from the Dual System that more than one company was needed to run New York's subways. The city demanded that Interborough Rapid Transit and Brooklyn Rapid Transit finance the railways or they could lose their leases, and they complied. The significance of this event is that the city was able to use capital from these current companies to finance the \$302 million large-scale construction that was under way.

From the Dual System emerged the Triborough System. This system made it possible for the subway system to run to Brooklyn, Manhattan, Queens, the Bronx, and Staten Island. It expanded New York's underground transit immensely. Connecting the rest of the city was the main goal, and the system runs through those very boroughs today.

The culture surrounding New York's subway has been shaped by its innovation. In 1941, underground transit had a huge role in the war effort. During this time, steel and rubber came under military demand, which automatically put the auto industry at a dead stop. People fled to the subway for their transportation needs. Another important feature was that citizens could seek shelter in it should Germany raid the city with flying bombs. So, it provided a sense of relief to the people of the city during World War II in more than one way.

At the present time, New York City subways, like its city, never sleep. They run continuously, every day, all day, to accommodate the needs of passengers. The life of New Yorkers revolves around the transit system and its dependability.

Peg A. Lamphier

See also Vol. 1, Sec. 3: Railroads

Further Reading

Cudahy, Brian J. 1979. *Under the Sidewalks of New York: The Story of the Greatest Subway System in the World*. Brattleboro, VT: S. Greene Press.

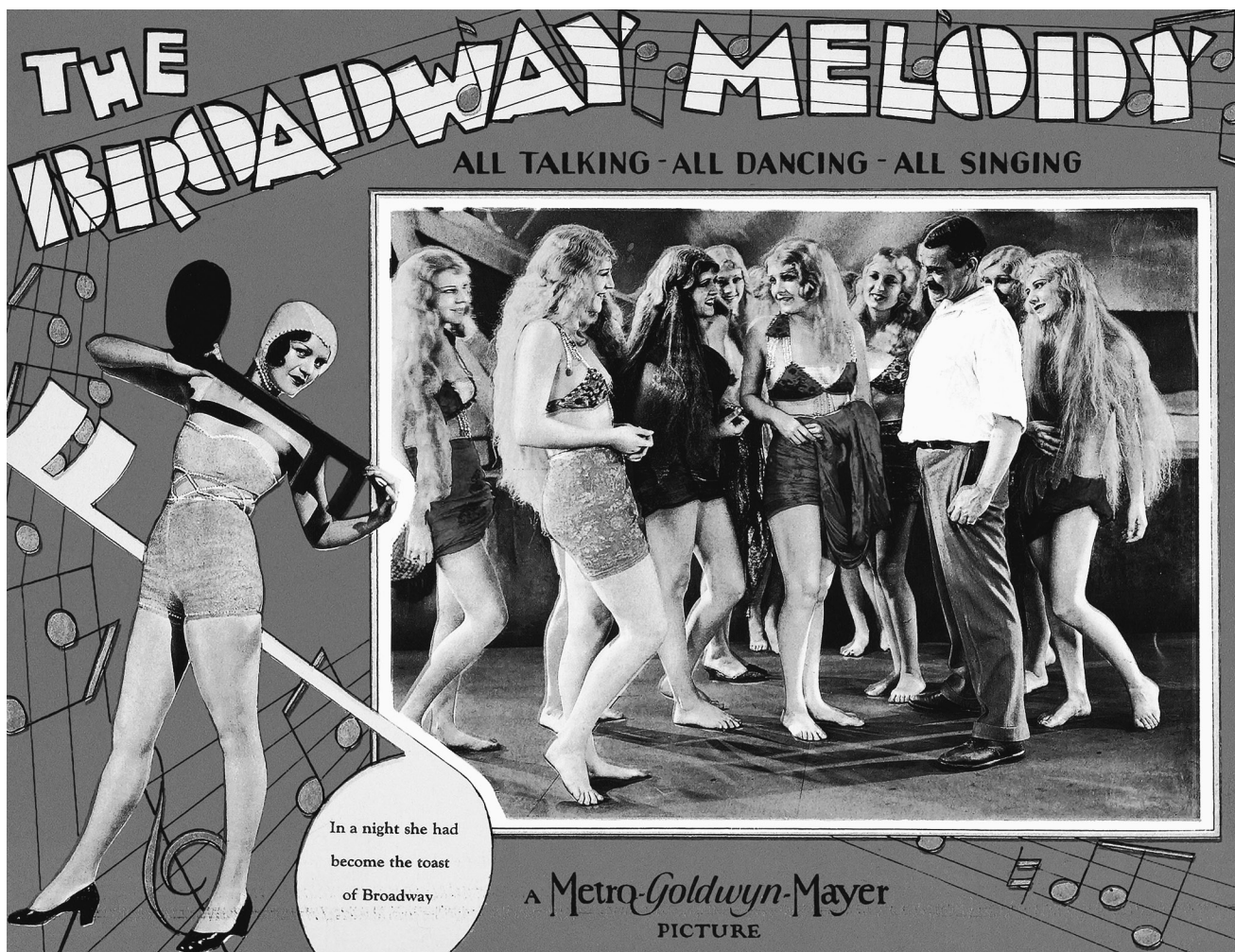
Heller, Vivian, ed. 2004. *The City Beneath Us: Building the New York Subways*. New York: W. W. Norton.

Talking Movies

The 1927 Warner Brothers movie *The Jazz Singer* became the first feature-length motion picture with synchronized dialogue sequences. This “talkie” would become the most profitable movie to date, but, more important, it augured the potential drawing power of talking movies. This new potential was transformed into a new industry business model.

The history of the movie business is the foundation of today's entertainment business, representing the confluence of communications technology, popular culture, and leisure time. Its birth goes back to American inventor Thomas Edison and the company Eastman Kodak. The process for making moving pictures was patented in 1891 using Edison's camera, the Kinetograph, which took a series of instantaneous photographs on a new Eastman Kodak celluloid emulsion film. The film was played back using a Kinetoscope. Edison introduced the new movie process at the Chicago World's Fair of 1893. Edison was the first to go into movie production at his Orange, New Jersey, laboratory. A great marketer, Edison took these short films to be marketed in a movie parlor known as a “nickelodeon,” which debuted in 1905 in Pittsburgh. Nickelodeons exploded, with 4,000 opening in two years. The potential seemed unlimited.

Edison had a virtual monopoly on the film business until 1908. Still, patent challenges and litigation bottlenecked the whole industry. In 1908, the major companies, including Edison, joined in a combine known as the Motion Picture Patents Company (MPPC). Eastman Kodak agreed to supply film only to MPPC. Even so, a government antitrust suit was not needed, as MPPC failed to monopolize the emerging market, especially as foreign companies entered the competition. The MPPC suffered from its own methodology, which required short feature films, lacked marketing, and ignored customer wants. It was an engineering-driven business model. Movies were limited by MPPC to a reel of film (about 1,000 feet), which



The Broadway Melody was the first talking movie to win an Academy Award for Best Picture. It was also the first all-talking musical. (Universal History Archive/UGC via Getty images)

lasted for about 30 minutes. This was yet another example, like in the case of early autos, of engineering aspects, rather than consumers, defining the market.

European film companies demonstrated the market popularity of feature-length (greater than 30 minutes) historic epic films such as *The Fall of Troy* (1911) and *Quo Vadis?* (1912). The American independents formed together under the Universal Film Manufacturing Company to produce feature-length films in 1912. In 1914, a new film distribution company, Paramount Pictures, emerged to distribute independent films. Another company, Triangle Corporation, proved the market potential of feature-length films by releasing some as long as two-and-a-half hours in length. Such feature films brought the medium into the realm of creative art,

which increased the need for writers such as Anita Loos and Frances Marion and directors such as Lois Weber to work together with producers to please modern audiences.

World War I created a shortage of European silent movies, which led to the rise of Hollywood. Hollywood injected the science of marketing into film production. Prior to 1914, most movie production took place in New York because of Edison's dominance, but the year-round filming opportunities in Hollywood won out. Film production became more consumer oriented as former nickelodeon and theater owners such as Warner Brothers, Universal Studios, and Paramount entered the movie business. Studio production allowed for feature film production. The studios looked to new

themes, such as the comedies of Charlie Chaplin and Buster Keaton, the westerns of Tom Mix, and the adventures of Douglas Fairbanks. Output boomed, reaching over 800 feature films by the early 1920s, with Hollywood studios accounting for over 80 percent of the world's production.

The big breakthrough augured by the success of *The Jazz Singer* was that of sound. The technological breakthrough came out of Western Electric's Bell Laboratories in New York. It was a "sound on disc" system called "Vitaphone." The sound track was not on the film but on a separate 16-inch phonograph. Warner Brothers purchased the Vitaphone and used it on its feature film, *Don Juan*, to add music and sound effects but no dialogue. Prior to this, theaters often hired musicians to provide background music at the theater. While having restricted technical specifications, the Vitaphone did launch the talkie with the 1927 *Jazz Singer*. The talkie turned the financial fortunes of Warner Brothers around, making it competitive with the "Big Five" studios: First National, Paramount, MGM, Universal, and Producers Distributing. Like so many pioneers, the Vitaphone inspired new inventions because of the market success of talking films. Within a few years, better sound-on-film processes emerged, such as the Fox Movietone and RCA Photophone system.

The use of sound caused major changes in the market. More complex mystery films evolved, such as Alfred Hitchcock's *Blackmail* (1929). Of course, the classic Hollywood musicals appeared, such as *The Broadway Melody* (1929) and *42nd Street* (1933). Wall Street took notice, with a major loan by Goldman Sachs to Warner Brothers. Warner Brothers pioneered the first all-color, all-talking movie, *On with the Show* (1929), which would become the industry standard. As the cost of producing rose, advertising increased to improve the gate take.

Quentin R. Skrabec

See also: Radio; Vol. 2, Sec. 1: Edison, Thomas; Phonograph

Further Reading

Carringer, Robert L. 1979. *The Jazz Singer*. Madison: University of Wisconsin Press.

Crafton, Donald. 1999. *The Talkies: American Cinema's Transition to Sound*. Berkeley: University of California Press.

Eyman, Scott. 1997. *The Speed of Sound: Hollywood and the Talkie Revolution, 1926–1930*. New York: Simon & Schuster.

Finler, Joel W. 1988. *The Hollywood Story*. New York: Crown.

Traffic Light, Electric

As cars became ever more prominent in the early 20th century, the invention of the electric traffic light was clearly inevitable. The electric traffic light brought a much-needed order out of the chaos that arrived with the technology that is the automobile. As the popularity of the automobile rose in society, the invention helped promote safety and efficiency on the streets.

In the early 1900s, roads in the United States were becoming crowded with people out and about in various modes of transportation, whether on foot as plentiful pedestrians, pedaling on bicycles, or riding in cars, which often still made use of horses. The period was a unique time in which both horses and automobiles shared the same pavement. The number of accidents involving automobiles grew, and consequently, so did fatalities. While the number of carriages began to dwindle, the boom in the automobile industry was just getting started.

The dangers posed by the increasing number of cars led to new ways for society to navigate the streets. These included traffic islands in 1907, the division of streets with paint in 1911, and signs that disallowed left turns for cars in 1916. With the spread of automobiles, traffic police appeared in cities to combat problems, particularly in intersections. They conducted the flow of cars by hand, but traffic lights run by gas also became popular in the United States. They had originated in London and were first used on December 9, 1868.

There were many attempts made worldwide to create the first electric traffic light, but on August 5, 1914, the first went up in Cleveland, Ohio. At the cross streets of Euclid Avenue and East 105th Street, a pair of green and red lights were placed at each corner of the crossing, thanks to the inventor James B. Hoge. Not only did these run electrically, but Hoge

designed the traffic lights with the fire and police departments in mind. His lights were controlled nearby from fire or police boxes, also known as substations, and manually switched by traffic police officers. Hoge also created a system of signals for communication between the substations and the actual fire and police stations.

Justin Matela

See also Automobile Technologies (Pre–World War II); *Vol. 3, Sec. 1: Automotive Technologies (Post–World War II)*

Further Reading

Finch, Christopher. 1992. *Highways to Heaven: The Auto Biography of America*. New York: HarperCollins.

Hoge, James B. 1918. Municipal Traffic-Control System. U.S. Patent 1,251,666, filed September 22, 1913, and issued January 1, 1918.

Triode Tube

The triode tube is a vacuum tube capable of amplifying an electronic signal. Patented in 1908 by inventor Lee de Forest (1873–1961), it consists of an evacuated glass case, or envelope, that contains three electrodes. The triode was an important invention for radio and electronics and was the precursor to the transistor.

On November 13, 1906, de Forest was granted a patent for his first Audion tube, which contained only two electrodes—a negatively charged cathode and a positively charged anode. This device was based on an earlier tube design by British electrical engineer J. A. Fleming (1849–1945), appropriately called the “Fleming valve,” or thermionic diode.

Like the Fleming valve, the Audion allowed electric current to flow in only one direction. De Forest began experimenting with the Audion’s design. He added a third electrode in the form of a metal screen between the cathode and anode, which he called the “grid,” using a setup consisting of an evacuated glass tube connected to a 22-volt battery and a set of headphones. When current was applied to the vacuum tube, de Forest could hear clicks through the headphones.

De Forest discovered that by applying a very small current to the grid or changing its electrical polarity, he was able to control the amount of current reaching the anode. The triode could also be completely shut off, thus functioning like a valve. On February 18, 1908, de Forest received a patent for this new version of the Audion, the first triode tube, although it would not be called by that name until 1919.

De Forest used his triode to detect and rectify (change alternating current to direct current) radio signals, but it was not until 1911, when electrical engineer Edwin Armstrong (1890–1954) realized that the Audion could amplify electronic signals, that the triode became of widespread interest for telephone and telegraph purposes. In 1912, de Forest sold the rights for the triode to the American Telephone and Telegraph Company, a decision that he would later regret.

De Forest’s early triodes were prone to feedback, which produced a howl or squeal in the headphones. Other engineers worked on reducing the noise problem, notably Finnish engineer Eric Tigerstedt (1887–1925), who refined the triode’s design and improved its amplification by rearranging the electrodes and making several improvements that reduced interference with the radio signals.

Triode tubes were used commercially throughout the 20th century, although most were replaced by solid-state electronics. In recent years, audiophiles and electronics hobbyists have created a renewed demand for triodes.

Karen S. Garvin

See also de Forest, Lee; Radio; *Vol. 2, Sec. 3: FM Radio*

Further Reading

Adams, Mike. 2012. *Lee de Forest: King of Radio, Television, and Film*. New York: Copernicus Books.

Cheung, Derek, and Eric Brach. 2011. *Conquering the Electron: The Geniuses, Visionaries, and Scoundrels Who Built Our Electronic Age*. Lanham, MD: Rowman and Littlefield.

Corbin, Alfred. 2006. *The Third Element: A Brief History of Electronics*. Bloomington, IN: AuthorHouse.

Turbine Engine, Gas Powered

The engine is arguably one of the most “American” inventions of all time, powering the treks of Americans from the country’s early days of expansion. While the steam turbine engine contributed greatly to the movements of Americans, the shift to a gas-powered turbine engine greatly improved the ways in which both material and people were transported. Not only was the gas-powered turbine engine much more efficient, it also benefited from being simpler in design and required smaller machinery to operate.

The theory of a turbine engine existed long before it ever materialized. Around the 16th century, Leonardo da Vinci drew a prototype for what resembles a gas engine. His invention involved a fire that would blow hot air, in turn rotating a gear and set of chains. The first emerging turbine engines, though, were run by water, or more specifically, by steam, controlled by temperature, pressure, and direction. A jet of steam was aimed in such a way that it would rotate turbine wheels. The blades on the turbine wheels provided even more efficiency, as the steam would be carried through and push the assembly with more ease.

As years went by, the steam turbine engine was regarded as the choice for power, especially for ships. By the 20th century, the invention saw modifications to further improve its performance. These changes included an alteration in shape for the blades to reduce friction, therefore maximizing the amount of power gained from the engine to do work. While the updates were progress on the technology, a more significant development was the introduction of the gas-powered turbine engine.

In 1899, Charles G. Curtis developed the gas-powered turbine engine, which would soon replace the steam turbine engine in numerous ways. Curtis was also among those who led the way toward a gas-powered turbine engine. Even after the modifications toward a better steam turbine, at most, the useful energy from it was 15 percent of what it generated. About 60 percent of the energy created by the steam turbine is lost, disappearing simply as undirected evaporation and a considerable amount of heat loss.

The gas-powered turbine does not use steam, and it utilizes a fuel for combustion to create mechanical

motion. Unlike the thermal energy in steam, the fuel for gas turbines has greater thermal efficiency, or the amount of work produced from the amount of heat generated. Another case for the gas turbine over the steam turbine was that temperature and pressure are proportional to thermal efficiency and overall mechanical work, and so, the higher the temperature and pressure of the system, the higher the system’s efficiency. Temperature and pressure of this magnitude proved difficult for steam to reach, while gas has an easier time of it.

In addition, a steam turbine engine required numerous bulky apparatuses to support its energy production, such as boilers and furnaces. Not only did these pieces of necessary equipment take up too much space, they were also heavy, which was not favorable when placed on a ship. The inevitable maintenance and repair of these machines grew quite expensive, and in comparison to their output of energy, they became impractical. The gas-powered turbine engine lessened the required space and weight, and it was simultaneously more efficient in cost and energy.

Justin Matela

See also *Vol. 1, Sec. 2: Internal Combustion Engine; Steam Engine*

Further Reading

- Curtis, Charles G. 1899. Apparatus for Generating Mechanical Power. U.S. Patent 635,919, filed June 24, 1895, and issued October 21, 1899.
- Hempstead, Colin A. 2005. *Encyclopedia of 20th-Century Technology*. New York: Routledge.
- Suppes, Galen J., and Truman Storvick. 2007. *Sustainable Nuclear Power*. Burlington: Elsevier Academic Press.

Victrola. See Gramophone/Victrola

Washing Machine, Electric

The electric washing machine has been a household staple since its first introduction at the turn of the 20th century. Clothes were first washed by hand and then

with simple machines requiring manual labor, but the wash became significantly less of a hassle with the electric washing machine.

In ancient times, washing clothes often involved natural sources of water such as rivers or lakes, and an abrasive surface, like a rock. The most well-known tool used for doing laundry before the washing machine arrived was the washboard. Typically made out of metal (although glass has also been used), washboards helped change the way people washed clothes. This could be done at washhouses, or places in town in which water was sourced; washing clothes required being away from home. It became the norm for women to be relegated to cleaning the family's clothing, and the idea that laundry was solely the wife's job promoted bonding between women, as they would come to wash their items at the washhouses and discuss their lives.

A mechanical washing "machine" was invented in the mid-1800s needing less manual labor than washboards but still requiring physical movement. It consisted of a drum with blades inside that would be rotated by hand via an attached handle.

In the early 1900s, the way people did laundry soon changed. Washing machines with cranks for spinning were by then seen as outdated, and people were looking for ways to modernize how laundry was done. In 1908, the Hurley Machine Company of Chicago introduced the electric washing machine, the Thor washer. While many may dispute who made the first electric washing machine, the Thor washer was still no doubt a key contribution. Being the very first to be commercially sold in the United States, the washer was designed by Alva J. Fisher, an engineer at the company.

The Thor washer was driven by motor rather than manually by the user like previous washing machines. The machine had a tub, and inside was a large, hollow cylinder that would spin a certain number of complete revolutions as the clothes inside tumbled in soapy water. After reaching the right number of spins, the machine reversed direction, which, along with the blades within that lifted the clothes apart, was meant to prevent clothes from clumping altogether. The invention, as Fisher had aimed for, provided a more efficient and less tedious way for women to wash clothes.

Justin Matela

See also *Vol. 2, Sec. 1*: Electric Iron; Ironing Board

Further Reading

Cowan, Ruth Schwartz. 1983. *More Work for Mother: The Ironies of Household Technology from the Open Hearth to the Microwave*. New York: Basic Books.

Fisher, Alva J. 1910. Drive Mechanism for Washing-Machines. U.S. Patent 966,677, filed May 27, 1909, and issued August 9, 1910.

Strasser, Susan. 2000. *Never Done: A History of American Housework*. New York: Henry Holt.

Welding, Alternating Current

In 1919, Claude J. Holslag invented a new type of welding using the power of alternating current. A resident of Peekskill in the county of Westchester, New York, Holslag worked for the Electric Arc Cutting and Welding Company as well as for the New York Central Railroad. He was involved in World War I as an associate of the Emergency Fleet Welding Committee and, as such, was part of the development of electrode and alternating current welding.

Holslag won the Samuel Wylie Miller Medal in 1939 for carrying on his work in the American Welding Society, where he eventually owned 200 patents. Holslag also wrote papers on welding and authored the *Arc Welding Handbook* in 1924.

What Holslag discovered was that when the alternating current is high, the electrical arc is able to cut through the metal depending on the arc's length. This is an extremely difficult weld, because the right amount of electrical power has to be chosen for each type of metal being welded. Alternating current (AC) is different from direct current (DC) because the electrons go back to the electric source; it was a major advancement for welding technology because AC has a stabler arc for welding. An unstable arc means that its electric current keeps moving around and does not stay in one area; this is called "arc blow." The weld has to keep an arc that is stable enough; otherwise it will not come out well enough for the standards of the American Welding Society (AWS).

Holslag died on June 11, 1945, at the age of 60. At this time, he was president of the Electric Arc Incorporation in Newark, New Jersey. Holslag had played a major role in the creation of the American Welding Society. The board members and friends of AWS awarded Holslag for his thoughtfulness, honesty, and honor.

Rolando Avila

See also *Vol. 2, Sec. 1*: Electricity, War of the Currents; Tesla, Nikola

Further Reading

American Welding Society. 1945. "Claude J. Holslag." *The Welding Journal* 24: 748–50.

Electrical World. Vol. 73. New York: McGraw-Hill Medical.

Holslag, C. 1920. "A–C. Transformers for Arc Welding." *Transactions of the American Institute of Electrical Engineers* XXXIX, no. 2: 1435–47.

Welding, Automatic

Welding is a method of joining pieces of metal together through a fusion process using heat and gases. Automatic welding was invented in 1920 by P. O. Nobel, who was then working for the General Electric Company, which gave him the background to create a new type of weld. He developed it by using the arc voltage to control the feed rate of the electrode in direct current (DC). DC flows from the power source in one direction and does not go back to the machine, which only happens in alternating current. One can use either direct current or alternating current for welding, depending on what type of weld is desired.

Automatic welding was first used to help build up worn motor shafts and crane wheels. The automobile industry used it to make rear axle housings for vehicles. This was an era when welding became popular because industries were growing that increased the demand for joining metals together. Arc welding uses arc voltage and electrode wires and was mainly used to repair certain metals.

Automatic welding was one of the first welding styles that required electrodes. It required a long electrode to keep feeding into the arc, and the nozzle fed off the electrode, which allowed the weld to keep going. The nozzle contains a passageway that is connected to a source of gas or vapor supplied through an automatically controlled valve. Most welders had to adjust their angle of weld depending on what type of welding was performed.

Automatic welding prompted the use of shielding gas, which protects the weld from the effects of too much oxygen and nitrogen in the atmosphere. This makes the weld more durable and stable. Before the use of shielding gas, brittleness was a huge problem when welding two metals together. A solution of hydrogen, argon, and helium is used as the welding atmosphere in automatic welding.

Rosanne Welch

See also Welding, Alternating Current; *Vol. 1, Sec. 2*: Gas Tungsten Arc Welding; *Vol. 3, Sec. 1*: CO₂ Welding

Further Reading

Hashmi, Saleem, and Bekir Sami Yilbas. 2014. *Comprehensive Materials Processing*. Amsterdam: Elsevier, 2014.

"The History of Welding." Miller Electric. <https://www.millerwelds.com/resources/article-library/the-history-of-welding>, accessed August 29, 2018.

3. The Great Depression and World War II (1930–1945)

OVERVIEW

As the United States lay mired in the depths of the Great Depression, Franklin Roosevelt assumed the American presidency in March 1933. For three years, the country had waited for the return of the prosperity that President Herbert Hoover had promised was just around the corner. And yet, in reality, Hoover, the “Great Engineer,” a man who had made his reputation feeding Europe in the aftermath of World War I, had been unable to turn the tide as the Great Depression enveloped the nation. Into the void, the beneficiary of an electoral rebuke that would haunt Hoover for the rest of his life, came Roosevelt, who, exuding an optimism that belied both his own genuine concerns as well as the nation’s true economic situation, told the American people that they had “nothing to fear but fear itself.” The contrast could not have been more telling. Yet the government that Roosevelt was to lead found itself forced to seek answers to previously unasked questions. Some of the answers would ultimately result in efforts to address the impact of previous inventions and innovations that had fueled the economic growth of the first decades of the 20th century but which had also, in their own way, contributed to the economic downturn that had become the Great Depression. From a series of agricultural advances that made overproduction an often devastating fact of farmers’ lives to technology that made investing and the stock market seem more like a game than a process on which a family’s economic fortunes could be founded, Roosevelt’s New Deal programs would ultimately seek to harness and redirect existing technology while also encouraging new inventions and approaches, all with the goal of helping a nation that

was struggling to recover from the greatest economic downturn in its history.

No one was more innovative than Roosevelt. Approaching the governing process like an inquiring scientist, he declared, “It is common sense to take a method and try it. If it fails, admit it frankly and try another. But above all, try something.” His willingness to risk failure in pursuit of solutions, an approach not unfamiliar to the scientists and inventors whose efforts had sparked earlier innovations, represented a different approach to government, but one aptly suited to the distinctive needs of Depression-era America. Consequently, while scientists and inventors were moving ahead, creating new items and refining existing ones, a newly empowered government began to undertake its own innovative efforts in an attempt to respond to a society in need. Indeed, central to the New Deal was the development of innovative and creative governmental programs that marshaled and harnessed technology, both old and new, in an effort to serve the American people.

The New Deal Spawns a Technological Revolution

Few things better demonstrated this partnership of the 1930s than the New Deal’s creation of the Tennessee Valley Authority (TVA). Using modern technology and advanced engineering skills to harness the power of the Tennessee River, the complete project transformed a whole region of the country, ending literally decades of darkness and exposing residents to countless aspects of American life that they had been denied.

The TVA had its roots in a pre–World War I plan to construct a dam in the Muscle Shoals, Alabama, region, a place where the Tennessee River dropped 140 feet

over 30 miles and made it all but impossible for ships to travel farther up the river. In 1916, the federal government acquired the land, intending to build a dam whose ultimate purpose would be to provide sufficient power to produce explosives needed for the impending war effort. The war ended before the initial construction had been completed, and with its original purpose rendered moot, the land became the subject of a decade long tug-of-war over who would have control of its future use. Nebraska Senator George Norris spent much of the 1920s seeking to maintain public control of the area while pushing a plan to have the federal government develop it. His efforts had been stymied by a recalcitrant Republican Congress, but when Franklin Roosevelt, whose personal interests included regional planning, conservation, and public utilities, assumed the presidency, he threw his support behind Norris and pushed the Tennessee Valley Authority Act through Congress in the spring of 1933. The law was intended to improve the navigability of the Tennessee River, provide for flood control and reforestation of the area, and help with agricultural development in the area while also aiding in national defense through the creation of facilities that could produce nitrate and phosphorus for the government. Completion of the project, whose reach, given the fact that the Tennessee River flowed through seven states, would be extensive, represented a major engineering feat. But beyond that, the legislation called for the TVA to improve “the economic and social wellbeing of the people living in the river basin.” It was in response to this part of the legislation that FDR issued an executive order creating the Rural Electrification Administration (REA). The REA’s purpose was to bring electric power to rural areas that had not previously been served as private business did not think there was sufficient profit potential. The REA helped create over 400 rural electric cooperatives that brought electricity to almost 300,000 households by 1939. Too, the encouragement of the REA coupled with the example offered by its success led some private utilities to expand their services into rural areas.

The impact of this increased electrification was not limited to its recipients, for the access to electricity left them anxious to use the time- and energy-saving appliances that the electricity powered. Consequently, local appliance merchants also benefited from this advance. Indeed, the TVA set up the Electric Home

and Farm Authority (EHFA), which helped farmers secure low-cost financing that allowed them to purchase appliances like refrigerators, water heaters, and electric ranges at reasonable prices. All of this served to benefit the appliance manufacturers and the electric companies while also allowing a sizeable part of the nation’s population to join its fellow citizens in enjoying an improved quality of life. In the end, the projects ultimately represented an innovative effort that combined governmental resources and engineering expertise, both undergirded by a desire to include a greater number of citizens in the American experience.

No less impressive or significant were the efforts being undertaken out west, where the nation’s engineering corps put the same impressive talent to work in designing and constructing the Hoover Dam. That project, which created the largest man-made lake in the country—that, when full, held enough water to cover the state of Connecticut to a depth of 10 feet—presented unprecedented challenges to the Bureau of Reclamation’s engineers. However, upon its completion in 1935, the dam, which had become an unexpected tourist attraction during its construction, was both a marvelous demonstration of American engineering capability and a pioneering effort in the utilization of hydroelectric power. A monstrous structure, it processed the same amount of water as flowed over Niagara Falls, and the amount of concrete used to build the whole thing could have paved a road from New York City to San Francisco. The dam was the linchpin of a larger, multifaceted project aimed in part at irrigating, as well as helping with the growth of, small farms. In addition, it was designed to protect Southern California as well as Arizona from the floods for which the Colorado River was, unhappily, known. In a triumph of innovation and technology, it achieved all of those goals and more. Indeed, completed while the country was still struggling to emerge from the Great Depression, the Hoover Dam became a symbol of what the nation, undaunted by its recent challenges, could still achieve.

Reshaping American Life through Technology Large and Small

While the major projects like TVA, the Hoover Dam, and the aviation- and military-related advances whose importance would be so evident in just a few years, as

well as the other innovative New Deal programs that were reshaping the American economic landscape, got most of the attention, American ingenuity and creativity were in no way limited to “big ticket” items. Indeed, despite the nation’s economic trials, the United States witnessed the invention and development of countless items that were deeply appreciated at the most basic of human levels by a populace bruised and scarred by the Great Depression. In fact, in the midst of the Great Depression, any invention or development, no matter how small, that could help boost the national morale was particularly welcome. One such advance was the introduction in 1935 of canned beer, no small development in a country less than five years removed from Prohibition. It was also one that impacted the social dynamic, as people no longer needed to go to the local bar for a beer. Another item that made life a bit less onerous was the board game Monopoly. While a variety of small-scale versions had floated around since the early 1900s, Parker Brothers unveiled its version in 1935, and it became a national—and ultimately, an international—phenomenon, allowing a nation struggling to make ends meet to enjoy playing the role of the wealthy banker, real estate developer, and entrepreneur while taking financial risks that had no consequences.

Too, the introduction of the electric razor by Jacob Schick in 1930, an invention further refined by the Remington Company, which introduced its own brand in 1937, was a boon to men across the country. Meanwhile, the development of suntan lotion reduced the sunburns that often made a day at the beach a mixture of pleasure and pain, and the polarized sunglasses that debuted at this time also helped make the beach experience, one that could now include activities involving the newly introduced beach ball, all the more enjoyable.

General Electric’s introduction of the garbage disposal, as well as the debut of a new style of electric blanket, one in which the heated blanket rested on top of an individual, was welcomed in homes across the country. At the same time, DuPont’s development of nylon as a synthetic substitute for silk morphed into the very popular nylon stockings that were introduced in 1939—just in time for their production to be curtailed when the war effort required all nylon to be used for parachutes and not the newly stylish stockings. Neoprene, a synthetic rubber developed during the

1930s, suffered a fate similar to nylon, for its military uses precluded its commercial development until after the war. No less well received and appreciated by the nation’s long-suffering homemakers and cooks were the frozen foods invented by Clarence Birdseye at the start of the decade—and, of course, the creation of the chocolate chip cookie as well as soft-serve ice cream helped bring smiles to countless faces young and old. Teflon and freeze-dried coffee, both invented near the end of the decade, would also do much to ease the future burden on homemakers. The 1930s also saw the development of Plexiglas, Lucite, Teflon, latex rubber condoms, and tampons, all of which had a substantive impact on the daily lives of many Americans. So too did the shopping carts that made going up and down the aisles of the now well-established supermarkets a much easier task. In addition, clear adhesive tape and cellophane, originally intended for use in grocery stores, soon became a staple in the American home, and their use was aided by the development of an easy-to-use dispenser. And, of course, after years of experiments and trials, RCA’s unveiling at the 1939 New York World’s Fair of the first practical black-and-white TV set, a bulky machine to be sure, heralded what would, in the aftermath of World War II, prove to be a veritable cultural revolution. Yet, while many of the new inventions and innovations were beyond the reach of the masses who were still suffering, some addressed the economic divide that the Great Depression had revealed. Foremost among these was the opening of the first Laundromat. Recognizing that only the wealthy and those with electricity could have their own washing machines, John F. Cantrell developed the idea of “renting” the use of such a machine for an hour. With four machines in operation, Cantrell opened the first Laundromat, what he called a “Washateria,” in Fort Worth, Texas, in April 1934.

Modernizing Entertainment: From Radios to Roadsters

Modern communication continued to develop at an impressive rate with new developments large and small affecting the way people communicated in the broadest sense. In 1930, newscaster Lowell Thomas offered the first regular radio network newscast and in 1931 the first commercial teletype debuted. Early in

the decade, Ford began to include radios in some of their cars, while the FM radio was introduced in 1933. Indeed, radio was taking off in the 1930s, so much so that the government, seeing the need for its regulation, enacted the Communications Act of 1934, which created the Federal Communications Commission (FCC). As the Mutual Radio Network began operation that year, it was reported that half of all American homes had radios, and, of course, President Franklin Roosevelt had already begun to harness its potential political power through his “fireside chats.” Radio’s power was also reflected in the emergence of the CBS *World News Roundup* in 1938, an event met with a much more restrained response than that given to Orson Welles’s *War of the Worlds*, the radio drama that panicked the nation while also demonstrating the medium’s clear, but as yet not fully tapped, power. Beyond radio, that period also saw the introduction of stereo records as well as the first tape recorder able to be used for broadcasting. While its true impact would not come until later, the development of the electric guitar, which debuted in the 1930s, would subsequently revolutionize the music world. The film industry was enhanced as Disney adopted a new three-color Technicolor process for its cartoons, an approach that was adopted by live-action films just a few years later. Too, the film *Napoleon* moved the film industry into uncharted territory as it debuted stereophonic sound, while Disney offered the first full-length cartoon when *Snow White* arrived on the screen in 1937. The invention of the photocopier in 1937 as well as the emergence of the ballpoint pen both played a continuing role in communication, but they, like the advent of fluorescent lamps for interior use and the unveiling of the desktop phone, were, in fact, more typical of the growing number of developments that made office work more comfortable, efficient, and productive. And while years of continued research, refinement, and developments lay ahead, efforts such as at Bell Labs and the Massachusetts Institute of Technology were underway to develop and build prototypes of the computers that would revolutionize the world a few decades later.

At the same time, many of the advances in the New Deal era were simply refinements and improvements of existing products. This was very much the case in

the world of photography, which continued its evolution into the 1930s with the introduction of stop-motion photography, Polaroid photography, the zoom lens, the light meter, and Kodachrome color film. Too, Kodak introduced 8-millimeter film for the ever-popular home movies. And, of course, few things reflected the nature of American life better than the latest round of car-related developments. As noted, some of the high-end cars rolling off Ford’s assembly lines in the early part of the decade featured radios, but safety concerns raised by the ever-greater number of cars on the road led to more practical advances like the development of the road reflector and the introduction of the yield sign. Too, with the increasingly crowded urban streets, the ever-growing number of cars on them, and the increasingly active government’s need to fund their efforts, the development of the parking meter, which made its debut in 1935 in Oklahoma City, Oklahoma, was inevitable.

Meanwhile, other scientific advances included the development of the black light as well as the Richter scale to measure the severity of earthquakes. At the opposite end of the scientific measurement spectrum, there was the development of the pH meter, which could measure the acidity of liquids, a substantive aid in health-related issues.

Entertainment during the Great Depression was the ultimate double-edged sword, as tight budgets limited what people could afford, and yet the need for diversion and things that could lift people’s spirits as well as the nation’s morale was, in many ways, more important than ever. At the same time, those realities did not stop the ongoing efforts to improve existing options while developing new ones. The development of the chairlift reflected the increasing popularity of skiing for those who could afford it in those troubled times, while the development of the bass guitar in the mid-1930s heralded a post-World War II musical revolution.

Technology Turns to the War Effort as World War II Looms

Of course, unbeknownst to the inventors and developers at the time, many of the advances that arose during the 1930s, products of a country stuck in the throes of

the Depression, would ultimately have an incalculable impact on the nation's efforts in World War II. Indeed, the early part of the decade saw a new round of developments in the aviation field, with the invention of both the first jet engine and the first turboprop engine. In looking back, it became clear that, as one analyst noted, "The 1930s saw a tremendous period of growth in aircraft technology—all-metal skin, enclosed cockpits, retractable undercarriages and increased armament capabilities." Too, in 1939, as the New Deal drew to a close and World War II loomed, the first helicopter arrived on the scene. In fact, many of the inventions of the 1930s, coupled with ongoing developments in existing aircraft, were critically important in World War II. As the nation moved deeper into the 1930s, the potential threat posed by the European war and Adolph Hitler's Nazi regime could not be ignored. While still in economic distress, Americans showed little desire to get involved in what most saw as a European conflict. At the same time, however, the United States did continue to develop armaments that could be used if peace efforts failed. Indeed, as the decade rolled to a close, considerable amounts of American technological expertise and talent were being directed to developing things that might help in that effort. It was not always an easy process, for a variety of postwar congressional investigations into U.S. involvement in the Great War had raised questions about the role of the American arms merchants and financiers in the U.S. entry into that earlier conflict. Those questions, coupled with the deeply unsatisfying end of that conflict with the failure of the United States to ratify the Treaty of Versailles and the U.S. absence from the League of Nations, did nothing to make the American people anxious to get involved in another war in which their interests did not appear to be directly threatened. But that sentiment did not stop the development of war materials, whether with an eye to sharing them with others whose efforts could preclude future U.S. involvement or simply to be at the ready should the United States ultimately become involved. Large amounts of time and money were being invested in the development of new items as well as the refinement and improvement of existing ones.

In fact, during the period between the end of World War I in 1918 and the U.S. entrance into World War II

in December 1941, the nation's military aviation capabilities and equipment underwent a complete transformation. The open-cockpit biplanes, usually made of wood, which had characterized World War I aerial efforts, had been replaced by all-metal monoplanes with four times the horsepower of their First World War predecessors as well as the ability to fly at altitudes of 30,000 feet. Indeed, the planes developed in the 1930s, aircraft that were at the heart of the wartime American Air Force, were technological marvels able to reach speeds of almost 250 miles per hour, over twice that of the standard World War I planes. In addition, the development of radar, the newly developed, gyroscopically driven flight instruments, and the electrical cockpit lighting allowed not only for nighttime operations but also for missions to be undertaken despite adverse weather.

Interestingly, many of the aviation developments of the 1930s that would prove so important to the war effort of the 1940s had their roots in the civilian air racing that was popular in the 1920s. A highly entertaining activity during the Roaring Twenties, many of the high specialized racing biplanes were built by the Curtiss Company for the U.S. Army Air Corps and Navy. The innovative designs that emerged at that time would be further refined and adapted to the wartime needs of the United States, allowing individuals like Lt. James Doolittle, who was a champion racer in the 1920s, to become a star fighter pilot with the new equipment used during the war.

Meanwhile, the commercial side of aviation was also ready to move ahead in the 1930s. However, despite the fact that the needed technology was in place, the aeronautic community was essentially grounded by the nation's economic woes. Amid unprecedented levels of unemployment and poverty, advancements in commercial air travel were not at the top of the nation's economic priority list. However, as the government advanced and expanded its support of airmail carriers, it was, however unwittingly, laying the groundwork for expanded commercial operations. Indeed, the passage in 1930 of the McNary-Watres Act began the transformation.

Seeking to enhance its airmail delivery services, the government altered the way it compensated its airmail contractors, shifting from a system where

payment had been based on the weight of the deliveries to one paying according to available cargo space. This served as an obvious incentive to operate large aircraft. As a further incentive, the government also offered a bonus to the mail deliverers operating multi-engine planes as well as planes that were equipped with the latest and most up-to-date instruments. This encouraged the nation's developing airlines to increase the number and size of their aircraft, ones that were capable of—and would profit by—carrying more passengers. The whole policy launched an industry-wide race as United Airlines and Transcontinental and Western Airlines (TWA) contracted with Boeing and Douglas Aircraft, respectively, to design and build the necessary aircraft. Too, refusing to be left behind, American Airways also contracted with Douglas Aircraft. This early battle for control of the skies led to a full-scale competition, which resulted in the development of the Boeing 247 and the Douglas Commercial One (DC-1). It was soon followed by the DC-2 and the DC-3, which, by the end of the decade, was carrying 90 percent of commercial air traffic worldwide. Indeed, its broader utility was also evident in the fact that 10,000 were built to serve the U.S. Army in World War II. Meanwhile, given that many routes were over water and that airplane bases were cheaper to construct at sea than airports, Pan Am developed a fleet of seaplanes, and by the mid-1930s, the company had routes traversing both the Atlantic and the Pacific Oceans.

All these advances ultimately helped make commercial aviation a comparative bright spot in the sputtering 1930s economy. But at the same, the aviation industry was also helping, however unintentionally, in the effort to advance the nation's military capabilities, a need that grew ever greater as the situation in Europe grew more threatening. Indeed, the European situation forced the United States to rethink the aviation policies that, since the end of World War I, had seen the airplane as primarily a defensive weapon whose only real responsibility would be to defend American shores.

However, as a growing number of Army Air Corps leaders came to envision the offensive possibilities of the airplane, efforts were undertaken to investigate and develop appropriate aircraft, with the B-17 bomber being the prime example. And in its own way, its development represented the intersection of the commercial

and the military development efforts, for when the Boeing 247 was rendered obsolete by the development of the DC-2 and DC-3, Boeing instead focused on a design competition sponsored by the army that sought to develop a new multiengine bomber intended for coastal patrol. Boeing's entry in the competition, a four-engine giant labeled the Boeing 299, made its first test flight in June 1935. The 299 not only won the competition but proved itself capable of outflying any other fighter plane, a status that quickly earned it a major contract with the Army Air Corps. And, of course, efforts continued into the 1940s and during the war itself to further develop the combat aircraft that would prove so important to the nation during World War II.

Wartime Inventions that Enhanced Postwar Living

As FDR announced that he had shifted roles from “Dr. New Deal” to “Dr. Win the War,” the nation increasingly focused on preparations for war. While this resulted in the development of new items like the jeep, a vehicle that would prove critical to overland travel in the European and African theaters (and would, of course, become a constant sight on the highways of postwar America), and new weapons, including napalm, flamethrowers, and smoke screens, not all the inventions and new developments that emerged in the early 1940s aided the war effort. Rather, as has often been the case throughout history, creativity mixed with adaptability and some plain old dumb luck led to some discoveries whose real true impact would be realized only in the postwar world. A prime example was the development of that all-purpose material, duct tape. Originally developed as a water-resistant tape intended for sealing ammunition cases, its many other uses were soon recognized, and it became a necessary part of anyone's home repair kit. Other discoveries of the period that would become a part of postwar life were Silly Putty and the inimitable Slinky. Too, new products developed just before the war, like plastic wrap (used instead of tinfoil), cardboard milk containers that replaced glass, and innovations like fiberglass, polyester, and plastic that would be central to life in the 1950s, also had their roots in war-based experimentation and development. And, of course, there was also penicillin. Originally developed in England in 1928, the British

worked on it over the next decade and a half, but problems with the development and a lack of resources necessary to produce it on a large scale hampered them. When the British contacted American pharmaceutical companies about it, they were interested but leery of the demands that production would make. Finally, the drug's potential value became so clear that the U.S. War Production Board assumed oversight of its production in 1943—clearing the way for a drug that would revolutionize postwar health care.

The advent of World War II continues to color the debate about the impact of the New Deal on both American economy and society. Yet as we look back on a nation that emerged from the Depression of the 1930s to build a war machine that helped save the world from the threat of fascist domination, there can be no denying that at least part of the nation's rebound can be attributed to science and technological advances coupled with multifaceted governmental innovations. Some of these clearly had an obvious impact, while others were not only more subtle but would not, could not, be fully recognized until sometime in the future. That is certainly true regarding the many military-based advancements, most of which their developers hoped would never be needed but were determined to have ready if they were. Indeed, as the New Deal began to fade into history and the 1930s slowly made way for a new decade, the nation looked ahead to a still-uncertain future. And yet it did so while able to take comfort in the fact that, in no small part due to shrewd use of its scientific, technological, and innovative abilities, it had proved its resilience in responding impressively to an unprecedented crisis. There was no reason to believe that it could not do so again.

This singular period, one that saw the United States emerge from the depths of an unprecedented economic depression to a position of unparalleled world leadership, came to an end in August 1945 when one of the most momentous scientific achievements of all time, the atomic bomb, was unleashed and ended World War II. While its impact was undeniable, so too was the potential for further devastation clear. Indeed, as the world cast its gaze on its war-torn self, it could also contemplate a future dedicated to recovery. Meanwhile, the United States could look back on a decade and a half of momentous change and accomplishment. Still, it had to recognize its responsibility in taking the

lead to confront the unprecedented challenge of how to best harness and direct—for the best interests of both a very different society and a very different world—the incredible power that had been unleashed with the atomic bomb.

William H. Pruden III

Further Reading

- Constable, George, and Bob Somerville. 2003. *A Century of Innovation: Twenty Engineering Achievements that Transformed our Lives*. Washington, D.C.: Joseph Henry Press.
- Gordon, Robert J. 2006. *The Rise and Fall of American Growth: The U.S. Standard of Living since the Civil War*. Princeton, NJ: Princeton University Press.
- Watkins, T. H. 1990. *The Great Depression: America in the 1930s*. New York: Little Brown.

Alaska Highway

The Alaska Highway is a 1400-mile stretch of highway that connects Alaska to the contiguous United States through Canada.

In the 1920s, the U.S. Bureau of Public Roads director, Thomas MacDonald, envisioned a connecting roadway between the United States and Canada, which would be Alaska's link to the contiguous United States. Canada initially saw no value in the project, stating that the only Canadians who would benefit from the roadway numbered in the low thousands. The Canadian government agreed to construction in 1929. Progress halted in the 1930s because of the Great Depression, but the road was finally completed in 1942. The attack on Pearl Harbor was the inciting event for the completion of construction, for the motives of the United States and Canada were more aligned than in previous discussions due to the war effort.

Contributions to the war effort included key access points to airports and military equipment. Supplies were shipped from Great Falls, Montana, to Fairbanks, Alaska, and the road was the prime transportation route in 1943. The highway assisted in saving more lives in the armies of Canada, the United States, and Great Britain, and led to a more refined and quick war. The highway is also seen as a key factor in the postwar



Two construction workers walk across a half-built bridge over a tributary of the Peace River in Canada. Built in 1942 to connect the contiguous United States to Alaska, the Alcan Highway had been proposed as early as the 1920s but became more important during World War II. (Library of Congress)

development of the Alaskan and Northern Canadian regions.

The dedication of the workers to complete the task in such rugged and cold terrain did not go unnoticed. A 1942 *Times* article reported that nearly 40 percent of railway workers were African American, saying that they had a significant role in the creation of the highway. Brigadier General Clarence Sturvaden commissioned the all-black Regiments 93 and 97 to work on segments of the road, because other generals were hesitant to supply them. The 93 and 97 had to do manual labor and with more effort than more adequately equipped regiments would have had to.

The Alaska Highway had been planned to be 1700 miles long, but with reconstruction and rerouting, it became slightly shorter. It was also originally highly

impractical due to steep grades, quick switchbacks, and rocky terrain. The public was told that the roadway was finished in 1942, but it was not. While the road has been straightened and paved since, it is still not a journey for the fainthearted. A stimulus of tourism to the area, increased populations in remote Alaskan and Canadian cities, and increased economic activity proved the route integral. Mines opened, tourism activities drew in revenue, and consequently, nature was adversely affected.

Environmentally, the highway disturbed the area's pristine prewar conditions. Bulldozers and asphalt invaded the habitat of fauna and flora, causing a heavy environmental footprint in the Alaska-Canada region. Dumps lining the route that contained metal building equipment and wasted gear and materials raised

complaints from citizens to the Alaska Highway Commission. Thousands of creatures live nearby and are affected by the highway, not including the thousands of human emigrants it brought to the land.

The Alaska Highway could also be called the Pan American Highway because unofficially, it stretches from the northernmost tip of Alaska to the southernmost tip of South America.

Rianna Hernandez-Thorn

See also Interstate Highway System; *Vol. 2, Sec. 1: Asphalt*; Transcontinental Railroad; *Vol. 2, Sec. 2: Panama Canal*; *Vol. 3, Sec. 1: Trans-Alaska Pipeline*

Further Reading

Chandonnet, Fern, ed. 2007. *Alaska at War, 1941–1945: The Forgotten War Remembered*. Anchorage: University of Alaska Press.

Coates, Kenneth S., and William R. Morrison. 2015. *The Alaska Highway in World War II: The US Army of Occupation in Canada's Northwest*. Norman: University of Oklahoma Press.

Wonders, William C. 1994. *Alaska Highway Explorer: Place Names along the Adventure Road*. Victoria: TouchWood Editions.

Primary Document: Excerpt from Ruth Gruber's Study of Highway Routes to Alaska (1941)

In 1941, the secretary of the interior appointed photojournalist Ruth Gruber as field representative to the Alaska Territory. Her job was to complete a study of the Alaskan frontier and report on natural resources, homesteading opportunities, and the Alaskan highway. A Jewish activist, she thought Alaska might be a good place to relocate Jewish refugees from Nazi Germany.

Stretching up in the distance, as we neared Talkeetna, was Mount McKinley. The tallest mountain peak in North America, it was a sculpted mass of ice and snow and rock.

Once again I became aware of how empty this land was, how easily newcomers and refugees could have lived here, liberated from the fires burning in Europe . . . Peggy Gordon . . . owned a successful dress shop in midtown. Sweltering in the heat, I dropped in and chatted with her. Because laundering was so costly (blamed like everything else on the high cost of transportation), it was cheaper for me to buy a new white blouse each week from Peggy than to have the one from the previous week washed and ironed.

Peggy had spent twelve years “Outside”—in the lower forty-eight—bringing up her son, who was now thirty, and her daughter, who had been “Miss

Fairbanks.” Moving back to Alaska, Peggy became the head of the Women’s Club in Anchorage. But in Fairbanks, where she now lived, she was too busy running her shop to go to meetings.

“I’m really in love with this town,” she told me. “The people here are so warm and democratic. Everybody digs in. It’s awfully hard on women though. They have to keep the fire burning all winter. The days are short, and it gets so cold, and there is so much to do, but there is a real heroic spirit.” She nodded, watching me jot her words in my notebook. Then she went on. “The real trouble with Alaska,” she said, lowering her voice confidentially, “is that Alaskans think they are so much better than everyone else who comes up here. They think they are just the best people in the world.” She conjured up an image of Alaskans standing with one leg on the gravy train and the other leg free to kick everyone else off.

Her husband, Frank, a small man with a shock of white hair and a Scottish brogue, entered the shop. He was a member of the legislature, and for long intervals left Peggy alone while he worked on bills and committees in Juneau. He joined the conversation as if he were making a speech.

“I’d like to see ten or twenty thousand people come up here when they build the Alaska Highway.

But the think I have against your boss Ickes is that he wanted to bring six hundred thousand refugees here."

"No, Frank," I said to the legislator, "the bill Ickes tried to introduce would only have brought five thousand Jewish refugees a year to Alaska." I shook my head, thinking, *This is the way anti-Semitism takes root.* "The Big Lie."

Where did Frank get the six hundred thousand figure? Oddly, it was the number of people Moses had taken from Egypt to the Promised Land, a mass escape from bondage that led to freedom for a mixed multitude.

Source: Ruth Gruber. 2002. *Inside of Time: My Journey from Alaska to Israel*. New York: Basic Books.

Atomic Bombs/Nuclear Weapons

The atomic bomb was a revolutionary type of weapon with previously unseen destructive capability. World War II saw the development of increasingly aggressive weaponry, and the advent of nuclear weapons heralded an era in which nearly instantaneous mass destruction was possible and the risk that humankind could cause its own extinction became a real threat. Along with the invention of such powerful weapons came moral questions regarding if and when their use, resulting in extreme loss of human life, was justified. When the United States dropped two atomic bombs on Japan to end the war in the Pacific, a dangerous new standard had been set, and many countries invested in nuclear weapon programs.

The discovery of the weapon potential of nuclear reactions was first credited to German scientists Otto Han and Fritz Strassman, who both accidentally discovered the secret to splitting uranium atoms in 1938. Even though they had successfully split the uranium atom, the process of creating nuclear weapons was a long journey from there. During this time, Jewish scientists in Germany began to flee to the United States to escape the Nazi threat. Many scientists had feared that Germany would produce nuclear weapons, and so they warned the authorities in the United States. Albert Einstein and the physicist Leo Szilard wrote a letter about this to President Roosevelt, explaining that Germany could cause mass destruction if it built nuclear weapons and urged him to have the United States develop them. Roosevelt agreed to do research and development. This was kept top secret, and the work was named "the Manhattan Project."

Colonel Leslie R. Groves oversaw the Manhattan Project, which took many attempts to unravel the true

potential of nuclear bombs. In 1942, plutonium was created by the chemist Glenn Seaborg. This new material had greater nuclear power than other elements and was much easier to manufacture. Much of the development process went into designing the bomb and determining the amount of power it would release.

Although the United States had begun the process of creating an atomic bomb, several other countries had similar goals. Despite Germany being the first to split the uranium atom, it got sidetracked and was not able to complete nuclear arms first. Japan also made little progress.

The first U.S. nuclear test, named "Trinity," occurred in Los Alamos, New Mexico, on July 16, 1945, in an unoccupied, open field. When the Trinity test was performed on a steel tower, there was an abundance of heat, an immense mushroom cloud that surrounded the area, and the release of explosive energy that erased the tower. The test was a success, and the nuclear age was born, supported by the likes of famous scientists and mathematicians such as Albert Einstein, Enrico Fermi, and Richard Feynman. After the success of the Trinity bomb, more research went into enhancing and refining it.

For the Allies, the scenario of the Axis using nuclear weaponry would lead to destruction and downfall. On April 12, 1945, Harry Truman became the president of the United States as tensions between the Allies and Axis powers increased. On August 6, 1945, President Truman announced the attack on Hiroshima, revealing the Manhattan Project to the public. As the news spread, people had mixed emotions about the use of nuclear weapons—there was opposition, and there was support. Some said that triggering the bomb was inhumane, and that such a drastic action was ill supported. Others said that the bomb would end the war

sooner, fewer lives would be taken, and it could have averted an invasion. Protesters marched in the streets to express opposition.

The most significant turning point in the history of nuclear weapons was the dropping of the atomic bombs named “Little Boy” and “Fat Man.” “Little Boy” had dropped on Hiroshima on August 6, 1945, causing mass destruction and the loss of many lives, including the annihilation of the city. The second bomb, named “Fat Man,” was much more powerful and was dropped on Nagasaki on August 9, 1945, causing the immediate death of around 40,000 to 70,000 people. On August 10, 1945, after these bombings, Japan surrendered, signaling an end to World War II.

While many celebrated the end of a long war, others had mixed feelings about the victory, posing questions regarding the ethics and morals that had been pushed aside during the war.

The development and use of atomic bombs in World War II had introduced a new standard in the way wars were fought. As the United States was the first to test and use the atomic bomb, other countries are now faced with the pressure to create such weapons to meet the standard. Atomic bombs and their impact have become one of the most significant shifters of history. For the first time, the thought had been introduced that a single country could hold the power to annihilate another as well as to end a war. Nuclear weapons had revealed the immense power that we could wield. Although the atomic bomb was used as a solution by President Truman for ending World War II, the aftermath and effects of executing such power and destruction led to a new era of more countries mass-producing nuclear weapons as a means of both protection and threat.

Amy Lou

See also Hydrogen Bomb; Manhattan Project

Further Reading

- Lee, Lacy. 2015. “Crucible of World War II: Harry Truman and the Atomic Bomb.” *Army Magazine* 65, no. 5: 62–64.
- Malloy, Sean L. 2010. *Atomic Tragedy: Henry L. Stimson and the Decision to Use the Atomic Bomb against Japan*. Ithaca, NY: Cornell University Press.

Avenger Field

Avenger Field is located in Sweetwater, Texas, and was the home of the Women Airforce Service Pilots (WASPs) of World War II. The WASP flight school opened at Avenger Field on February 21, 1943, and was the first all-women military flight-training facility. The school closed on December 7, 1944.

The War Department had considered using female pilots as early as the 1930s, but despite the efforts of pioneer aviators Jacqueline Cochran (1906–1980) and Nancy Harkness Love (1914–1976) to promote the use of women pilots in an emergency role, women were not allowed to fly for the military until 1942.

In 1938, the U.S. government established the Civilian Pilot Training Program (CPTP) to train pilots in anticipation of military conflict. Twenty thousand civilian pilots were to be trained each year to provide a pool of candidates for the armed forces. The CPTP allowed women to train but limited the number of female pilot trainees to 1 woman for every 10 men.

The Women’s Auxiliary Ferrying Squadron (WAFS) was established in September 1942 and placed under the leadership of Love, who by this time had logged more than 1,200 hours of flying time and had a commercial pilot’s license. Love sent out telegrams to 83 women who had more than 500 hours of flight time. From that group, she recruited 27 experienced pilots to serve in the Ferry Command in a civilian capacity. These women, along with Love, became known as “the Originals.”

The WAFS pilots ferried aircraft from the factories to airfields and were initially limited to flying light aircraft and training vehicles, although they later flew larger planes, such as the P-51 Mustang, a long-range fighter plane, and the B-25 Mitchell bomber. The WAFS contribution to the war effort released male pilots for active duty, but at only 28 pilots the organization was too small to be very effective.

In 1942, General Hap Arnold (1886–1950) authorized the establishment of a women’s pilot-training program, the 319th Army Air Forces Flying Training Detachment (Women), better known as the Women’s Flying Training Detachment (WFTD). Cochran was appointed as director. Air Transport Command (ATC) created a 23-week pilot training course at Houston

Municipal Airport in Houston, Texas, for the women. The first class began in November 1942 as part of the 319th Army Air Force Women's Flying Training Detachment (AAFWFTD). Twenty-three women pilots graduated on April 24, 1943. They were instructed in basic flight training, cross-country navigation, and safety but received no combat training.

The WAFS and WFTD merged in 1943 to become the WASP. In February 1943, while the second class was in progress, the WASP relocated to Avenger Field in Sweetwater, Texas, and its flight-training program was expanded to 30 weeks. Previously a municipal airport, Avenger Field was leased to the War Department and used as a training ground for Royal Air Force and American pilots. In April 1943, Avenger Field became an all-female base.

WASP classes started monthly, and a total of 18 classes graduated between 1943 and 1944. More than 25,000 women applied to the program, but only 1,074 graduated from training and became pilots. The WASP was a paramilitary organization, but the female trainees lived in barracks, wore uniforms, and engaged in military-style physical training.

These civil service female pilots were assigned to 120 air bases nationwide. Their duties ranged from serving as flight-training instructors and glider tow pilots to towing targets for gunnery practice and transporting cargo. The WASP delivered more than 12,000

aircraft nationwide and flew 78 types of airplanes, including the legendary B-29 bomber the *Enola Gay*. Some of the better pilots were allowed to work with jet- and rocket-propelled planes and radar-controlled targets.

On September 30, 1943, the first bill was introduced in Congress that would have given the WASP full military status. The bill met with political resistance, as did further efforts to militarize the organization, and the WASP was ordered to disband by December 20, 1944. Avenger Field's flight school trained 232 women before ceasing operations in 1944.

Karen S. Garvin

See also B-17 Flying Fortress; Curtiss-Wright Aeronautical Engineering Cadettes; Rosie the Riveter; Women's Airforce Service Pilots (WASPs)

Further Reading

- Carl, Ann B. 2010. *A WASP among Eagles: A Woman Military Test Pilot in World War II*. Washington, D.C.: Smithsonian Institution Press.
- Cole, Jean Hascall. 1992. *Women Pilots of World War II*. Salt Lake City: University of Utah Press.
- Rickman, Sarah Byrn. 2001. *The Originals: The Women's Auxiliary Ferrying Squadron of World War II*. Sarasota, FL: Disc-Us Books.

Primary Document: Letters of Mary Anna Martin Wyll, a Pilot Trainee at Avenger Airfield (1944)

The Women Airforce Service Pilots (WASPs) trained at Avenger Field during 1943 to 1944. Eighteen classes of female pilots trained there. The following are several letters from one of those pilot trainees, Mary Anna Martin Wyll.

Letters from Avenger Field, 318th AAFSTD [Army Air Forces Flying Training Department], May 1944–December 1944.

Dearest Mother & Dad:

Gee, what a long day this has been. We came out in 2 huge semi-trailer trucks with benches arranged

in the trailer, and have spent the entire afternoon marching here and there and in lengthy lectures from the chief of staff, the primary training (flying) officer, the flight surgeon and the physical training teacher. So far, I'm thrilled beyond measure.

Got a glimpse of the flight line when we went down to the hangers to get our flying "zoot-suits" (Army fatigues) and other flying equipment.

18:00

Just got back from getting the rest of our uniforms. The stuff has cost me only \$15. This is everything I believe.

Betty Phillips met me at the hotel and has been over quite a few times today.

Taps—

Dearest Mother, Dad, Louise, Grandma and Berne Dean:

Well I've certainly had a taste of Army life. It's really rugged. We hardly have time to see the inside of our bays—Even our evenings are full of meetings and lectures.

We go on the flight line every day and I get thrilled about flying each time. Today they closed the PT flying during my period, hence, I didn't get to fly. Mr. Bingham talked to us students (5) for about 1 1/2 hours which was just as helpful as actually flying. The wind velocity gets very high here, that's why we didn't fly today.

I eat sand here all the time, but that's 100% better than battling with hot weather and insects. (I even like the snakes down here).

The other day I saw my first black widow spider. There are quite a few around here.

We had a fire drill last nite. It was quite complete. The fire engines even came around and hooked up the hose—just to wash the sidewalks which [sic] we stood out in the field in formation freezing to death.

You've never seen such whiz kids as we are in our bay. This morning we were up at 6:00, cleaned up the bay, made our beds, dressed and were in formation for breakfast at 6:25. At seven were sitting in class. Ground school was over at 10:00. 10:15 we went to drill. Then we were free to read our mail from 11:45–12:00. We changed our clothes and reported for the flight line at 1:30. At 7:00 left the flight line and ate dinner at 7:30. After dinner we thought well, we can rest until morning, but the officer of the day announced "There will be a meeting of all trainees at 21:00". This is my day!! For the life of me I can't see where I've had the chance to gain 5 lbs. (I weigh 118 now).

Maybe Saturday I'll have a chance to mail my laundry bag back home.

Goodnight and love,
Mary Anna

Thursday, June 15

Dearest Dad:

Happy Dad's day! I've got some good news for you. I hope it will compensate for flowers or somepin.'[sic] I soloed yesterday. It was a wonderful feeling and made Mr. Bingham quite happy. Today I soloed again which makes my total solo time 20 minutes and total dual 9 hrs and 56 minutes. We have been really hep on flying this week. The instructors are all anxious to get his students soloed. Mr. Bingham's five were all soloed by today. It's a grand old feeling to be up there alone.

The most thrilling thing just happened a few minutes ago. Three B-17's (Flying Fortresses) buzzed the field in formation and then peeled off to land one at a time. A jeep rushed out to the planes and took the pilots to the O.D. [Officer of the Day] office. By that time everyone had rushed to the flight line to get the deal. Guess why they came. To pick up the girls from W-5 for a dance tonight. The girls in the graduating class were guests of honors. Wouldn't that be wonderful to go to a dance about 100 miles away in a B-17. I hope that happens to W-10 around in December.

I'll let you in on a little military secret (supposedly). Miss Cochran was here this week. She ate in the dining room with W-10 this noon. She's very charming and makes you at home.

Dad—I hope you have a happy Dad's Day. I'll be thinking of you. Last Sun. it was Louise now it's Daddy.

Love

Mary Anna

Source: Nancy Marshall Durr, ed. *Mary Anna Martin Wyal: WASP Letters, 1944–1945*. Women Airforce Service Pilots. Denton: Texas Women's University, Special Collections, 1994. <http://cdm15075.contentdm.oclc.org/cdm/ref/collection/p214coll2/id/5153>, accessed August 29, 2018.

B-17 Flying Fortress

The Boeing B-17 Flying Fortress was created in the 1930s to help aid the U.S. Army Air Corps (USAAC) during the strategic bombing of World War II. It was first known simply as Model 299. It did not gain its

"Flying Fortress" moniker until *Seattle Times* reporter Richard Smith called it that due to its many machine-gun mounts. Soon after, Boeing trademarked the name.

The Boeing B-17 Flying Fortress was the first modern bomber, created when the army requested a multiengine bomber. The prototype took less than 12

months to develop from the design board to the flight test. In the end, the plane contained four engines, a flight deck, and contained bombs along with five mounted .30-caliber machine guns.

The first B-17 went to war in 1941; however, as the war intensified, more armor and weapons were needed. This led to the next generation of B-17, called the B-17E, the first mass-produced model of the Flying Fortress. This model differed from the prototype in that it had more machine guns—nine—and a greater weight of bomb load at 4,000 pounds. Each version of the Boeing B-17 Flying Fortress became more heavily armed.

The next B-17 model created was the B-17G in 1943. The B-17G still had four engines; however, the gun count increased to 13 and the bomb load to 6,000 pounds. Wright Aeronautical licensed Studebaker to create the engines in the Boeing B-17 Flying Fortress. The B-17 contains the Wright R-1820 Cyclone 9 engine. It produced about 1,200 horsepower with a maximum speed of 287 miles per hour. Along with that, the B-17 was 74 feet 9 inches long with a wingspan of 103 feet 9 inches. It had a cruising speed of 150 miles per hour and could fly up to 3,750 miles. The B-17 was able to hold a crew of 10, which included two pilots, a bombardier, a navigator, a radio operator, and five gunners.

By May 1945, before the end of production, 12,726 B-17s had been produced. Of that total, 8,680 were the recent G model. The B-17 continued to be used until the end of the war, until the Boeing B-29 “Superfortress” was created and replaced the B-17. As of 2015, only 13 B-17s were still in operation but were featured at museums or air shows. The majority of B-17 planes were scrapped at the end of the war.

Sydney Nguyen

See also *Vol. 1, Sec. 3: Machine/Gatling Gun*

Further Reading

B-17 Flying Fortress. <http://www.boeing.com/history/products/b-17-flying-fortress.page>, accessed August 29, 2018.

Hyde, Charles K. 2014. *Painted Turtle: Images from the Arsenal of Democracy*. Detroit: Wayne State University Press.

Tucker, Spencer C. 2015. *Instruments of War: Weapons and Technologies That Have Changed History*. Santa Barbara, CA: ABC-CLIO.

Big Science

“Big science” is a term used to describe the scientific research done during and after World War II. Big science encompassed the research that went into the scientific disciplines of physics, astronomy, and, later on, biology. Large-scale projects were conducted by groups of scientists and technicians, funded by the government. Big science differs from “small science,” which involves individuals or small groups creating a theoretical result. Projects such as the Hubble Space Telescope and the Apollo Program are examples of some well-known “big science” projects.

Before big science, science focused on creating basics or a platform for further research. For example, in the early 1800s, the goal of the chemist was to isolate and describe elementary substances and their properties as well as compounds of chemically active radicals of elements. It wasn’t until the late 1860s that the periodic table of elements was mapped. As for physicists, they focused on the study of mechanics, optics, and acoustics. It was not until the mid-19 century that physicists began doing experiments. By the end of the 19th century, many physical and chemical laboratories resembled factories with their output. While World War I did not affect everyday science, World War II dramatically changed the scope of the discipline.

The term “big science” became popular in 1961, as first mentioned in the article “Impact of Large-Scale Science on the United States” published in *Science* by Alvin M. Weinberg. He wrote it in response to Dwight D. Eisenhower’s farewell address, in which he warned of the danger of the “military-industrial complex.” Also at this time, the U.S. government was sponsoring big projects such as the Manhattan Project (the American atomic bomb program) and the Radiation Laboratory. In Weinberg’s article, he criticized how the then-current era of big science might negatively affect science in general, while expressing a sadness for the disappearance of small science.

Weinberg asked three specific questions: First, was big science ruining science? He stated that space research was not worth the money; he considered the effort wasted. Also, he believed that when too much money goes into a certain field, it becomes more focused on money than actual research, which makes the discipline “fat and lazy.” Second, was big science

ruining scientists financially? He stated that during the era, 10 percent of the federal budget, about 1.6 percent of the gross national product then, went to the funding of science. He explained that unless something could be done, within 65 years, all funds would focus on science and technology to the detriment of other areas of study. Last, he asked if scientists should divert more effort toward issues that bore more directly on human well-being than on such big-science spectacles as manned space travel and high-energy physics. Weinberg felt that we should not allow ourselves to be diverted from creating better human lives. In the end, he encouraged his colleagues to limit big science to the national laboratory system to prevent it from emerging in the universal system.

Still, many scientists began to study big science both in and out of a laboratory. Just a few years after Weinberg's article, Derek J. de Solla Price published *Little Science, Big Science* in 1963. It described how small science had given way to big science, describing the differences between them. Price is also known for laying the foundation of "scientometrics," which is the "science of science."

Although big science became popular during and after World War II, many questioned its validity against that of small science. Many did not like the idea that funds earmarked for smaller projects were being given to bigger projects. Also, due to the size of such research, big projects were given longer timelines than smaller projects, sometimes a decade or more. Many questioned whether big science projects were worth the price.

In this current era, a new term has been created to describe the type of science being done. "New big science" is large-scale research done at laboratories that is more focused on material science than, for example, astronomical research. Instead of exploring nuclear and subnuclear length scales, research in materials focuses on phenomena at atomic, molecular, and larger scales. Old and new big science differ in that old big science focused on the gradual increase of high-energy physics projects, increasing instrument size, collaboration, and experiment duration, while in new big science, there is no increase in instrument or collaboration size. The research ecosystem has simply grown and become more complicated. In new big science, scientists are involved in more fields, have access

to a more diverse instrument catalog, and have a faster turnover of research groups.

Sydney Nguyen

See also Atomic Bombs/Nuclear Weapons; Manhattan Project; *Vol. 3, Sec. 1*: Apollo Project; *Vol. 3, Sec. 3*: Hubble Space Telescope

Further Reading

- Broad, William J. 1990. "Big Science: Is It Worth the Price? A Periodic Look at the Largest New Research Projects; Heavy Costs of Major Projects Pose a Threat to Basic Science." *New York Times*.
- Crease, Robert P., and Catherine Westfall. 2016. "The New Big Science." *Physics Today*: 30.
- Dennis, Michael Aaron. 1999. "Big Science." *Encyclopedia Britannica*.
- de Solla Prince, Derek J. 1986. *Little Science, Big Science . . . And Beyond*. New York: Columbia University Press.
- Nye, Mary Jo. 1996. *Before Big Science: The Pursuit of Modern Chemistry and Physics, 1800–1940*. Cambridge, MA: Harvard University Press.
- Weinberg, Alvin M. 1961. "Impact of Large-Scale Science on the United States." *Science* 134, no. 3473: 161–64.

Blood Transfusion

Blood transfusions are very common in America to help boost low blood levels caused by surgery, injury, or diseases. The idea of using a blood transfusion to save a patient first came from William Harvey (1578–1657), an English physician who studied medicine in Padua, Italy, after graduating from Cambridge University in England. Harvey was the first person to understand the circulation of blood and publish his idea in *De Motu Cordis* in 1628. This led to an interest in transferring blood between animals, between humans, and between humans and animals.

The first successful blood transfusion occurred in 1665 in England. Richard Lower, a physician, conducted an experiment in which he transferred blood from one dog to another. This was considered a success when the dog survived. A couple of years later, in November 1667, Lower and another English physician, Edmund King, and Jean-Baptiste Den of France,

conducted separate experiments in blood transfusion involving an animal and a human. One experiment transferred blood from a sheep into the body of a human, and it was successful.

It was not until 1818 that the first blood transfusion from human to human occurred. James Blundell, a British obstetrician, was the first to do this as a treatment for postpartum hemorrhage. He concluded that only human blood should be transferred after observing that dogs given human blood always died. This led to a rise in blood transfusions from person to person.

It wasn't until 1901 that the first three human blood groups were discovered by an Austrian physician, Karl Landsteiner. This led to the idea of transferring blood by matching donors, which Ludvig Hektoen conceived and Reuben Ottenberg performed. Today, we classify blood types as A, B, AB, and O.

In the 1940s, the United States developed a national blood collection program. In 1941, the Red Cross established the National Blood Donor Service to collect blood for the U.S. military, with Dr. Charles R. Drew as medical director. This service was used to help injured soldiers during the Pearl Harbor attack. Controversy arose when Drew, a prominent African American medical doctor, protested the practice of racial segregation in the donation of blood, largely because it lacked a scientific foundation. When the American Red Cross maintained its policy of separating donated blood based on race, Drew resigned.

Nowadays, donated blood is used for direct blood transfusion. The process involves pumping blood and into a patient's blood vessel through an intravenous (IV) line and needle. The procedure takes one to four hours, depending on how much blood is being received. The patient is closely watched for the first 15 minutes to ensure there is no allergic reaction.

Sydney Nguyen

See also Vol. 2, Sec. 2: Drew, Charles

Further Reading

Giangrande, Paul L. F. 2000. "British Journal of Haematology." *Historical Review*: 758–67.

Lederer, Susan E. 2008. *Flesh and Blood: Organ Transplantation and Blood Transfusion in 20th Century America*. Oxford: Oxford University Press.

Bradberry, Henrietta (1903–1979)

An African American Chicago housewife and relatively unknown inventor, Henrietta Bradberry, created a collapsible bed rack and method of discharging waterproof torpedoes. Though her first invention, the bed rack for clothes, was relatively forgettable, her second invention, the device for discharging torpedoes underwater, was an important creation that helped the Allies in World War II. Despite the importance of her invention to the war effort, Henrietta Bradberry was largely lost to history, and she remains largely unknown. Although unsung, Bradberry's ingenuity as an inventor, and particularly as an African American woman inventor in this field, cannot be overstated.

Not much is known about Bradberry. She was born in 1903 in Franklin, Kentucky. After she married William Bradberry, they moved to Chicago, Illinois, where she created her two inventions and filed for their patents. She only graduated high school, but this did not deter her from inventing. In an interview, Bradberry explained that the ideas for her inventions came to her as she did chores. Bradberry used her free time to improve her inventions to the satisfaction of the Patent Office.

In 1943, she was awarded the patent on her collapsible bed rack, which she had filed for in 1941. The bed rack was attached at the foot of the bed to hang and refresh lightly worn clothes in the air. Clothes were hung on rods to let them dry out and so that fresh air circulated, alleviating odor in the days before washing machines were commonplace. The rack was collapsible with a pedal that raised and lowered it. Though not a very complex or revolutionary invention, it proved to be Bradberry's entry to the patent world.

Two years later, Bradberry filed for a patent for her pneumatically operated device that fired torpedoes underwater. In 1945, during World War II, she was awarded the patent. The complex device was operated pneumatically (with air or gas under pressure) and could fire multiple underwater torpedoes from submarines and subterranean stations. The device had three gears, allowing the operator to discharge more torpedoes than the previous standard of just one. The device prevented water from coming into contact with and damaging the inner mechanisms that discharged the torpedoes.

Bradberry attempted numerous times, with the support of her patent attorney, to find willing manufacturers or buyers to buy out the patent rights. However, these aspirations never came to fruition. This may have been due to her lack of experience in inventing or to superficial reasons such as her race and gender. Disenchanted by repeated failures to gain from her hard-earned efforts, Bradberry never filed for other patents. She died on May 17, 1979, in Chicago.

Jose D. Avelar

See also Calutron Girls; Lamarr, Hedy; Military Technology (World War II); Submarine Technology; *Vol. 2, Sec. 2: Washing Machine, Electric*

Further Reading

Honey, Maureen. 1999. *Bitter Fruit: African American Women in World War II*. Columbia: University of Missouri.

Sluby, Patricia Carter. 1987. *Creativity and Inventions: The Genius of Afro-Americans and Women*

in the United States and their Patents. Tucson, AZ: Research Unlimited.

Sluby, Patricia Carter. 2004. *The Inventive Spirit of African Americans: Patented Ingenuity*. Westport, CT: Praeger.

Calutron Girls

The Calutron Girls were a group of young women who monitored dials for the Oak Ridge National Laboratory's spectrometer, or "calutron," that made the enriched uranium for the Manhattan Project for use in the first atomic bombs.

Calutrons used giant electromagnets to separate uranium-235 from uranium-238. The original calutron was developed at the University of California, Berkeley, but once the machine was fully operational, the university turned it over to the Tennessee Eastman Company, who hired young women to work in the calutron facility. None of these women had more than



Evelyn Babb, one of the original "calutron girls," hired by the U.S. government to work on the Manhattan Project at the nuclear weapons plant in Oak Ridge, Tennessee, died in 2015 at the age of 90. Just out of high school, Babb and other young women like her monitored the calutron, the machine that separated enriched uranium isotopes. (Ali Rizvi/McClatchy DC/TNS via Getty Images)

a high school education; nor did they know anything about the uranium separation or its eventual use in atomic bombs.

The women were trained to operate the laboratory machines but not told what the machines did. They lived in dormitories near the lab, for which they were charged \$10 a month. The women worked seven days a week in rotating shifts and were not allowed to speak to each other while they worked. In a contest between Berkeley scientists and the so-called hillbilly girls in Tennessee, the calutron girls outproduced their educated, male colleagues. Uranium enriched at the Tennessee labs was shipped to Los Alamos, New Mexico, for use in atomic bomb building.

Emma E. L. Burke

See also Atomic Bombs/Nuclear Weapons; Manhattan Project; *Vol. 3, Sec. 1: Mercury 13*

Further Reading

Kelly, Cynthia C., ed. 2010. *The Manhattan Project: The Birth of the Atomic Bomb in the Words of Its Creators, Eyewitnesses and Historians*. 2nd ed. n.p.: Tess Press/Black Dog & Leventhal.

Clarke, Edith (1883–1959)

Edith Clarke graduated from the Massachusetts Institute of Technology (MIT) in 1919 to become the first female electrical engineer in the United States. Unable to find work, she invented the Clarke Calculator and taught physics in Turkey before returning to the United States to work as an engineer for General Electric (GE). She became the first female engineering professor when the University of Texas at Austin hired her in 1947.

Born in 1883 to Susan Dorsey Owings and John R. Clarke, Edith was one of nine children. Her parents died when she was 12, after which her older sister raised her. She used money left to her at her parents' death to attend Vassar College, where she studied math and astronomy. She graduated in 1908 and took a job teaching at Marshall College, a private women's school, in San Francisco. She left San Francisco to

study civil engineering at the University of Wisconsin-Madison. In 1912, she got a job as a "computer" for American Telephone and Telegraph (AT&T). In 1918, she enrolled in MIT and a year later earned a master's degree in electrical engineering.

Having earned her master's, Clarke looked for an engineering job. She could find no one who would hire a woman as an engineer, so she took a job supervising the female "calculators" who did the math in GE's Turbine Engineering Department. In 1921, she filed for a patent for the Clarke Calculator, an early graphing calculator that solved current and voltage equations. Soon after, she left for the Constantinople Women's College, which had offered her a job. She taught in Turkey for two years before returning to the United States to take a job with General Electric in the engineering department. In 1926, she delivered a paper to the American Institute of Electrical Engineers (AIEE). She was the first woman to do so. The paper, which posited hyperbolic functions for calculating maximum electrical line power, won the Best National Paper Prize from the AIEE in 1941.

In 1943, while still working for GE, she wrote and published *Circuit Analysis of AC Power Systems*, a textbook based on lectures she gave to GE engineers. She published a second edition of the volume in 1950. Clarke retired from GE in 1945. Two years later, the University of Texas at Austin hired her as a professor in their Electrical Engineering department. She was the first female ever to be hired as an electrical engineering professor, as well as the first woman inducted into the AIEE as a fellow. She died in 1959. In 2015, the National Inventors Hall of Fame inducted her into their ranks.

Peg A. Lamphier

See also *Vol. 2, Sec. 1: Edison, Thomas*

Further Reading

Brittain, James E. 1985. "From Computer to Electrical Engineer—the Remarkable Career of Edith Clarke." *IEEE Transactions on Education* E28, no. 4 (November): 184–89.

Curtiss-Wright Aeronautical Engineering Cadettes

The Curtiss-Wright Aeronautical Engineering Cadettes was a cadre of young women who met a critical need for aeronautical engineers during World War II from 1943 to 1945. Unlike Rosie the Riveter and Wanda the Welder, the cadettes were the first university-trained female aeronautical engineers in the United States. In 10 months or less, the cadettes completed three years of graduate engineering course work. They were immediately employed in the development of the Curtiss-Wright SB2C Helldiver Bomber. In addition to bailing out an aviation company whose planes were vital to winning World War II, the cadettes' efforts proved that women were capable of excelling in the male-dominated field of aeronautical engineering.

The Curtiss-Wright Engineering Cadette program formed when aviation giant Curtiss-Wright was struggling with the engineering revisions required to improve its SB2C Helldiver Bomber. To meet the wartime shortage of male engineers, Curtiss-Wright partnered with seven universities to prepare female college students for a career in aeronautical engineering. Participants in the 1943 cadette class had to be 18 years of age and had to have completed one year of college and scored in the top third of their mathematics classes. The intensive course compressed two to three years of graduate engineering course work into 44 weeks. To avoid distractions from their family and friends, the young women were required to travel to a distant university. In addition to opening the door to engineering faculty and a career in aeronautical engineering with Curtiss-Wright, the program covered all expenses related to tuition, room and board, and travel. Also, as Curtiss-Wright employees, each cadette earned \$10 a week, then fairly good wages for a woman.

The cadettes' course load included advanced mathematics, applied geometry, drafting, flight theory and aerodynamics, aircraft materials, and stress analysis. Courses moved so quickly that cadettes joked that if one dropped a pencil and bent to pick it up, she would miss an entire course in algebra. In spite of the rapid pace, the program could not keep up with the demand for engineers. By 1945, the cadette program

was open to high school juniors and seniors, and the curriculum was further compressed, covering three years of content in six months. The cadette curriculum ran ahead by one year to prevent the girls from distracting the male students by asking for help. At final exam time, the cadettes outperformed the men. The top three scores went to female cadettes.

Of the 918 graduating cadettes, 365 were assigned to the Columbus, Ohio, plant and walked into an ongoing design nightmare. The U.S. Navy had commissioned a carrier-based, large-capacity dive-bombing aircraft called the SB2C (Scout Bomber Second Series Curtiss, or Helldiver), which defied basic principles of aeronautical design. Rather than being slim and streamlined, the fuselage (body) of the plane was short and wide with a large, heavy tail. To meet the parking requirement, the Helldiver's wings folded up to form a triangle over the body. Pilots found the massive plane hard to control, so they decided that "SB2C" meant "Son of a Bitch, Second Class." Others simply called the plane the "Big-Tailed Beast." Over four years, 889 design revisions would be required to address all of its problems. The cadettes were to translate the revised specifications into detailed, accurate production drawings, check the plans for accuracy, and inspect the planes on the production lines. Although their official title was "assistant engineer," the cadettes rarely saw a senior engineer on the production floor. In some cases, a 17-year-old cadette would be supervising the work of adult riveters and welders.

In spite of Curtiss-Wright's promises, the end of the war brought the end of the Curtiss-Wright Aeronautical Engineering Cadettes. On August 15, 1945, the radio pink slip arrived when newscasters in Columbus, Ohio, announced that the war was over and that Curtiss-Wright cadettes need not report to work. A few cadettes returned to Curtiss-Wright briefly to train the returning servicemen to take over their jobs. Federal legislation to support returning soldiers effectively shut women out of professional positions and the opportunity to study engineering. The majority of the cadettes started new careers as teachers and homemakers. The women who designed the planes that won the war became unsung heroines of the Greatest Generation.

Lynda C. Titterington

See also Avenger Field; Women's Airforce Service Pilots (WASPs)

Further Reading

- Douglas, Deborah G. 1990. *American Women and Flight since 1940*. Washington, D.C.: Smithsonian Institution Press.
- Lenthe, Jean-Vi. 2011. *Flying into Yesterday: My Search for the Curtiss-Wright Aeronautical Engineering Cadettes*. El Prado, NM: Wild Hare.

D Rations

D Rations, or military chocolate bars, were introduced during World War II to fulfill the need for an emergency energy source included in ration supplies for soldiers. The government commissioned the Hershey Company (known at the time as Hershey Foods Corporation) to create the product, which had to be high in energy content, weigh four ounces, withstand much more heat than normal chocolate so as to not melt on the field, and not taste exceptional—so as to dissuade the soldiers from eating the chocolate before necessary.

Army quartermaster Col. Paul Logan approached Hershey in 1937, and the bars, originally called “Logan bars,” were experimentally shipped out to be used in the Philippines, Texas, and Panama. From then on, the United States ordered the bars for soldiers in World War II, where they were universally viewed as having an unappealing and bitter taste and an overly chewy texture. Hershey Foods received the Army-Navy Production Excellence Award in 1942 for its involvement in the war effort, an honor given to only approximately 4,000 companies out of nearly 85,000 involved.

Rianna Hernandez-Thorn

See also Freeze-Dried Food; *Vol. 2, Sec. 1: Food Preservation*

Further Reading

- Cooke, James. J. 2009. *Chewing Gum, Candy Bars, and Beer: The Army PX in World War II*. Columbia: University of Missouri Press.

Electric Guitar

The electric guitar was developed to increase the volume of a guitar, which could not be heard above other instruments in jazz or swing bands. Originally, electric guitars were relegated to the rhythm sections of bands, but the advent of rock 'n' roll music made the electric guitar the preeminent instrument in modern popular music.

Early attempts to increase the volume of acoustic guitars led to the use of steel strings, bigger instruments, and the use of microphones connected to loudspeakers, which produced feedback. Lloyd Loar of Gibson mounted an electrostatic pickup on various archtop guitars around 1923, but Gibson was not yet interested in manufacturing electric instruments.

The Dopyera brothers built metal-bodied resonator guitars under the National and Dobro names, with metal discs mounted under the bridge to act like mechanical loudspeakers. Stromberg-Voisinet advertised an “Electro” with a magnetic pickup in 1928, but there is no evidence that it was ever manufactured. Historians therefore credit the Rickenbacker A-22 “frying pan” as the first electric guitar. Because of the popularity of Hawaiian music, which utilized lap-steel guitars, Adolph Rickenbacker, George Beauchamp, and Paul Barth formed the Ro-Pat-In Corporation to make electric guitars. Their aluminum-bodied lap-steel guitars, with magnetic horseshoe pickups designed by Beauchamp, came out in 1932 and were nicknamed “frying pans” due to their long-handled shape. The company was eventually renamed Rickenbacker.

Hawaiian guitars were played while resting on the player's lap; the player slid a bar along the neck, unlike with traditional, “Spanish-style” guitars. Gibson introduced the ES-150 (“ES” for “Electric Spanish”) in 1936, and other companies began making electric instruments as well. Electric Spanish-style guitars were hollow-bodied (acoustic) instruments to which magnetic pickups were added.

The two performers who helped popularize the electric guitar were Les Paul, who used an electrified Gibson L-50 archtop on the radio with Fred Waring's Pennsylvanians, and Charlie Christian, who played both a Gibson ES-150 and ES-250 with the Benny

Goodman band. Christian was enormously popular during his short life and, due to his recordings with Goodman, showed that the electric guitar could produce single-line solos like a saxophone or trumpet, transforming it from a rhythm to a solo instrument. Christian, who died of tuberculosis in 1942 at age 25, was so influential that Gibson's bar pickup is still called the "Charlie Christian pickup."

Vibrations from hollow-body guitars, however, interfered with vibrations from the strings, producing feedback and distortion, leading several designers to experiment with solid-body guitars. Les Paul designed "the Log" in the early 1940s, which was a solid block of wood with two pickups. Merle Travis commissioned a solid-body guitar from Paul Bigsby in 1947.

Leo Fender, who owned a radio repair shop, partnered with George Fullerton and was the first to successfully mass-produce solid-body guitars. Originally released as the Esquire with only one pickup, the Fender Broadcaster came out in 1950 and was made of a solid plank of ash with rounded corners, a single cutaway, two pickups, and a maple neck that was bolted to the body. Due to a trademark complaint, its name was changed to the Telecaster in 1951. It became extremely popular with country and western bands because of its twangy sound, and unlike electrified acoustic instruments, it had to be amplified to be heard. Conveniently, Fender also manufactured an amplifier. Fender had further success with the first electric bass guitar in 1951, followed by the Stratocaster guitar in 1954, which had two cutaways, three pickups, a tremolo bar, and a contoured body. It was quickly adopted by rock 'n' roll musicians, notably Buddy Holly.

Although Gibson resisted solid-body guitars for fear that they would tarnish its reputation for quality archtop models, the success of the Fender Telecaster prompted it to design a solid-body model that it brought to Les Paul for his endorsement. The Gibson Les Paul was issued in 1952 and had a two-piece, archtop body made of maple and mahogany, and two pickups. It later included "humbucker" pickups, a double-coil device that canceled hum.

John A. Drobnicki

See also Paul, Les

Further Reading

Millard, André, ed. 2004. *The Electric Guitar: A History of an American Icon*. Baltimore: The Johns Hopkins University Press.

Waksman, Steve. 1999. *Instruments of Desire: The Electric Guitar and the Shaping of Musical Experience*. Cambridge, MA: Harvard University Press.

Fermi, Enrico (1901–1954)

Italian American physicist Enrico Fermi is considered one of the principle nuclear-age scientists. He immigrated to the United States in 1939, the year after he received the Nobel Prize, fleeing Italian racial laws that negatively affected his Jewish wife.

Enrico Fermi was born in 1901 in Rome, Italy, to Ida de Gattis and Alberto Fermi. He went to college in Pisa, where he initially studied mathematics but switched to physics in 1920. His first two papers explored issues in relativity, the first connecting mass and movement and the second proving that electrical charge has weight. He earned his doctorate when he was 20 years old, after which he spent a semester studying with Max Born at the University of Göttingen. In 1924, he won a Rockefeller fellowship and studied with Paul Ehrenfest in Leiden. All the while, he, along with Einstein and others, was inventing the field of theoretical physics. In 1925, Fermi wrote a paper in which he posited a principle for particles later called "Fermions" and "bosons." Fermi would later postulate the existence of neutrinos, though they would not be discovered until after his death.

In 1926, he became a professor at the Sapienza University in Rome. His mentor in Rome, Orso Mario Corbino, was a member of Italian dictator Benito Mussolini's cabinet. Two years later, Fermi published a textbook in particle physics that gained him university sufficient fame that Sapienza became an important physics school.

In 1938, Fermi won the Nobel Prize in Physics for his discoveries in neutron irradiation and nuclear reactions. He went to Stockholm to receive his prize and from there went to the United States, fleeing the racist and anti-Semitic racial laws enacted in Italy and Germany. He took a job at Columbia University

and, while working with nuclear physicists, learned of recent advances in nuclear fission theory. Fermi joined a team of Columbia scientists including Eugene Booth, John Dunning, Herbert Anderson, Francis Slack, and Norris Glasoe in efforts to measure energy release from neutron-bombarded uranium. Fermi thought that fission could be achieved with blocks of uranium oxide if they used graphite, rather than water, to better encourage self-sustaining nuclear reactions. Fermi published the results of this work and in 1939 gave a lecture on it to scientists at the U.S. Navy. Not long after Albert Einstein (1879–1955) and other scientists sent President Franklin Roosevelt (1882–1945) a letter warning that Nazi Germany was surely working on a nuclear bomb and that the United States would be best served by developing that weapon first.

Thus, the impetus for the Manhattan Project at Los Alamos, New Mexico, was born. While others put together the New Mexico nuclear facility, Fermi and a team of scientists and engineers built a self-sustaining nuclear reactor at a facility outside Chicago in 1942. Fermi moved his research and family to Los Alamos in mid-1944, where director Robert Oppenheimer (1904–1967) made him associate director. Fermi took part in the research that culminated in a successful test of a nuclear bomb in July 1945 known as the Trinity Test. Fermi would measure the bomb site after the blast and calculate a 10-kiloton explosion. In reality, the explosion was almost twice that powerful at 18.6 kilotons.

Fermi next joined a committee to determine where the nuclear bomb might next be detonated. The committee agreed that the bomb should not be used without warning, but military authorities ignored the committee and dropped two bombs, one on Hiroshima, Japan, and the other on Nagasaki, Japan, on August 6 and 9 respectively. Fermi and the other Los Alamos physicists learned of the nuclear bombs the same way the rest of America did: from a radio announcement.

In July 1945, Fermi went to work for the University of Chicago, where he continued his work on nuclear reactions and theoretical physics. He mentored German American physicist Maria Goeppert-Mayer, who had also worked at Los Alamos and in

1963 won the Nobel Prize in Physics. Fermi died of stomach cancer in 1954. Today, he is considered one of the most influential physicists that ever lived. Indeed, though today Albert Einstein is far more famous, historians of science contend that Fermi's research, mentorship, and communication skills outstripped Einstein's. In 1956, the Atomic Energy Commission named its highest award after Enrico Fermi.

Peg A. Lamphier

See also Manhattan Project; Oppenheimer, J. Robert; *Vol. 2, Sec. 2*: Einstein, Albert; *Vol. 3, Sec. 1*: Goeppert-Mayer, Maria; *Vol. 3, Sec. 2*: Nuclear Energy/Nuclear Power Plants

Further Reading

Schwartz, David N. 2017. *The Last Man Who Knew Everything: The Life and Times of Enrico Fermi, the Father of the Nuclear Age*. New York: Basic Books.

Segre, Gino, and Bettina Hoerlin. 2016. *The Pope of Physics: Enrico Fermi and the Birth of the Atomic Age*. New York: Henry Holt.

FM Radio

Edwin Howard Armstrong (1890–1954) received four patents in 1933 for the frequency modulation (FM) method of broadcasting radio signals. He had been working to reduce static, an inherent problem with amplitude modulation (AM) broadcasts. While AM modulates a radio wave's amplitude to carry a signal, FM changes the frequency of the wave, resulting in a stronger, cleaner signal. Armstrong demonstrated FM's superiority by broadcasting from the Empire State Building, but competition from AM stations and patent suits threatened the nascent FM industry. After World War II, the Federal Communications Commission (FCC) reassigned the FM band to a higher range of the broadcast spectrum, and many FM stations were forced off the air. FM Radio made a comeback in the late 20th century. The industry recovered slowly, but by the late 1970s, FM stations outnumbered AM

stations considerably. FM radio continues to dominate the modern radio industry.

Karen S. Garvin

See also *Vol. 2, Sec. 1:* Tesla, Nikola; *Vol. 2, Sec. 2:* Radio; *Vol. 3, Sec. 1:* Transistor Radio

Further Reading

Woolley, Scott. 2016. *The Network: The Battle for the Airwaves*. New York: HarperCollins.

Freeze-Dried Food

The process of freeze-drying food has ancient origins. As early as 1250 BC, the Incas of Peru stored food crops in the mountains in winter. The cold would freeze it, and the low air pressure at high altitudes caused its moisture to vaporize, slowly drying it. This made food last much longer.

This process was not well understood until the early 1900s, when scientists needed to develop techniques to preserve human and animal tissues without damaging them. They found that freezing the tissue and then applying a vacuum to it would quickly force its water out in vapor form, preserving it virtually intact. In the mid-1900s, the process was applied to foods for the same reason—freeze-drying preserves flavor and color.

Freeze-drying's scientific name is "lyophilization." It is derived from Greek and literally means "solvent-loving process," as the freeze-dried product will rapidly reabsorb the water (or solvent) that was removed when it is added back in. The first freeze-dried food to be made commercially available was instant coffee.

Nancy Beach

See also *Vol. 2, Sec. 2:* Birdseye, Clarence

Further Reading

Freeze-Dry Foods, Ltd. 2015. History of Freeze-Drying. <http://www.freeze-dry.com/2015/09/29/history-of-freeze-drying/>, accessed August 29, 2018.



A researcher at the Food Science Department of Rutgers University observes the rehydration of freeze-dried pork chops. (Carsten/Three Lions/Getty Images)

Varshney, Dushyant, and Manmohan Singh, eds. 2015. "History of Lyophilization." In *Lyophilized Biologics and Vaccines*, 3–10. New York: Springer.

Garbage Disposal

Garbage disposals, also known as waste disposal units and "garburators," are electrically powered mechanisms installed between a sink drain and trap that are designed to shred or grind food into bits small enough to pass through household water pipes.

In 1927, Wisconsin architect John Hammes applied for the first garbage disposal patent. Hammes founded InSinkErator and began marketing his invention in 1940, five years after General Electric marketed its own garbage disposal unit.

The machine consists of a .5- to 1-horsepower motor that spins a circular table that runs the grinding chamber. Waste food enters the chamber and is ground by a sharp-edged cutting ring. Garbage disposal users

must run the water while the disposal unit is engaged so that it flushes the ground-up material down the pipes leading from the sink.

While the garbage disposal is a popular home mechanism, many cities prohibit their use on the grounds that they damage sewer systems. New York City had a longtime ban on garbage disposals for just this reason, until Environmental Protection Agency studies showed them to be safe. In 1997, New York City rescinded its prohibition against garbage disposals. Other cities followed soon after.

Emma E. L. Burke

See also Microwave Oven; Vol. 2, Sec. 2: Blender

Further Reading

Sobey, Ed. 2010. *The Way Kitchens Work: The Science Behind the Microwave, Teflon Pan, Garbage Disposal and More*. Chicago: Chicago Review Press.

Gas Mask

The Great War was not great—and to soldiers on the front line, it was definitely hell. Add to the dangers of trench warfare and the fear of being shot the fear of a gas so toxic it killed within minutes. Without the invention of the gas mask, more lives would have been lost or people maimed from the effect of breathing poisonous gases such as chlorine or mustard.

A gas mask is a small respirator to aid in breathing. It must fit securely to the wearer's face, tightly enough that no fumes enter from any openings other than the breathing area. There are several variations. As the wearer breathes in, the air passes through a filter, purifying it before it reaches the wearer's lungs. Filters vary from pads that purify the air and keep smoke or dust particles out to activated charcoal filters that trap toxic gases and vapors.

Some gases are so toxic that they can burn skin through clothes. The gas mask can help with some of these, but not all.

Linda Briley-Webb

See also Vol. 3, Sec. 1: Agent Orange

Further Reading

Hughes-Wilson, John. 2014. *The First World War in 100 Objects*. London: Firefly Books.

Simkins, Peter, Geoffrey Jukes, and Michael Hickey. 2013. *The First World War: The War to End All Wars*. Oxford: Osprey.

Golden Gate Bridge

The tallest suspension bridge in the United States, the Golden Gate was once also the longest and tallest in the entire world. Spanning 4,200 feet, reaching a height of 746 feet and a length of 8,981 feet, the bridge became an icon of the city of San Francisco shortly after its opening in 1937.

Though Joseph Strauss conceived the idea and served as chief engineer of design and construction, he had yet to work on a suspension bridge, so other experts joined the team—among them Leon Moisseiff, Irving Morrow, and Charles Alton Ellis.

Construction began on January 5, 1933, and officially concluded four years later on opening day: May 27, 1937. The process had been anything but smooth, beginning with the funding of such an infrastructure project. Strauss personally sought help from Bank of America president Amadeo Giannini, who provided a crucial boost by agreeing to buy \$6 million in bonds in 1932.

As it was the first of its type of bridge to span such a distance, many new ideas were involved. Moisseiff created the “deflection theory” by which a thin, flexible roadway would flex in the wind, greatly reducing stress by transmitting forces via suspension cables to the bridge towers. Eventually, 250 pairs of vertical suspender ropes were attached to two main cables. The group also created the idea of designing a “bridge within a bridge” to avoid the need to demolish a nearby fort that had historic value stretching back before the Civil War.

Safety became an issue in such a large project, and Strauss invented a movable safety net that stretched beneath the changing areas of daily construction, prepared to catch any workers who fell from the bridge. In the end, 19 men were saved by the new contraption, though at one point, an entire scaffold broke and fell into the net, which tore it open; 10 of the 12 men on that scaffold died. Calculations by the engineers claimed the bridge could withstand winds to about 70

miles an hour and recommended that it be closed on days of higher speeds. To date, that has only happened three times.

Rosanne Welch

See also *Vol. 1, Sec. 2*: Burr Truss Bridge; *Vol. 1, Sec. 3*: Brown Truss; Howe Truss; *Vol. 2, Sec. 1*: Brooklyn Bridge

Further Reading

Schwartz, Harvey. 2015. *Building the Golden Gate Bridge: A Workers' Oral History*. Seattle: University of Washington Press.

Starr, Kevin. 2010. *Golden Gate: The Life and Times of America's Greatest Bridge*. London: Bloomsbury Press.

Primary Document: Letter of Charles Ellis to the *San Francisco Chronicle* Regarding the Golden Gate Bridge (1930)

Though today the Golden Gate Bridge is widely considered one of the most beautiful bridges in the world and a true American icon, its construction was not without controversy. Chief engineer and designer Joseph Strauss employed Charles Ellis to do the principal engineering calculations for the bridge. Relations between the two men became strained when Ellis became convinced that the bridge's design was faulty. Strauss fired Ellis in November 1931. Strauss largely took credit for the bridge, though in 2007, the Golden Gate Bridge District formally gave Ellis credit for the bridge design. The following is an excerpt of a letter that Ellis wrote to the San Francisco Chronicle explaining his concerns.

March 11, 1930

Preliminary test borings completed. I left San Francisco for Chicago and started the preliminary design and estimate. I had many times tried to convince Mr. Strauss that a year would be necessary to do this work properly.

Plate girder, simple truss, arch and cantilever spans are very much alike in that they all perform their duties as a beam in resisting bending moments and shears. A suspension span is in a class by itself since it acts like a clothes line instead of a beam. Hence it is at once obvious that an engineer may be thoroughly familiar with all other types of bridges and yet be a novice in suspension span theory and design.

Such was the situation in our office. I could not turn over the computations to any one else but had to make them myself, and at the same time initiate one of our men, Mr. Clarahan, a former student of mine, into the fundamental theory. Mr. Strauss, however, insisted that the work must and could be done in three or four months, inasmuch as he would write the report in San Francisco while I was making the design and estimate in Chicago.

There was a large bascule bridge job going through the office at this time in charge of Mr. Paine on which a bonus was to be paid if completed on a given date and because of this, it was with much difficulty that I was able to arrange for the release of a few men to help me. By working twelve to fourteen hours a day I personally made all the computations and the entire design and with a few men at my command—at most six or eight at any one time—the plans were sufficiently laid out . . .

A meeting with the three consultants was held in Chicago to review the work. Mr. Strauss was also here. Three sessions were held on each of two days attended by the consultants and myself. During all these sessions except the last one when his report was discussed Mr. Strauss, the chief engineer, was not in the room once to sit down or take any part in the discussions. Subsequent to this meeting the plans were finished, tracings made and on August 22 I arrived in San Francisco with the preliminary plans completed. Mr. Strauss had meanwhile written his report in San Francisco so that it can be correctly stated that he knew as little about my plans as I knew about his report.

Some of the Directors who reviewed his report were not satisfied with it. I understand that the Directors cut out much of it and turned the remainder over to Mr. Taylor, the traffic engineer, to rewrite for publication. Several of the Directors and the General Manager asked me confidentially for my opinion of the report and my reply was that, since I was in Mr. Strauss' employ, I must decline to comment. Mr. Strauss, however, arrived at the erroneous conclusion that the dissatisfaction on the part of the Directors was traceable to me.

It was at this time that I first felt Mr. Strauss' displeasure. For years it had been thoroughly understood that I was to have charge of this work, and that

at the proper time we would transfer all the work to San Francisco where I would be located as Resident Engineer.

It was also understood that when the preliminary plans were delivered, I should remain in San Francisco and give technical advice during the bond campaign, but when he realized that the Directors were coming to me for information and advice he instructed me to return to Chicago at once.

November 4, 1930

Bonds voted. Mr. Strauss immediately sent for Mr. Paine who up to this time had had absolutely no connection whatever with the work or any other work of the suspension type. He was a former student of mine and was brought into the Strauss organization several years ago by me. He was in San Francisco about two weeks. Two days before his return to the office I received a letter from Mr. Strauss

which in effect took the work out of my hands and placed it in charge of Paine with no reasons or explanations whatever given for such a drastic action.

The only portion left in my charge related to the computations and specifications. This arrangement made an almost impossible situation since the computations, design, plans and specifications were all so closely interwoven that to separate them was simply inviting complications.

Probably the only reason the computations were left in my hands was because, with the exception of Clarahan who was just getting his initiation into this sort of work, I was the only man in the organization who had even the slightest conception of what the computations were all about.

Source: Charles A. Ellis papers, 1911–1946, Purdue University Libraries, Archives and Special Collections.

Helicopter

A helicopter is a type of aircraft that uses lift and propulsion supplied by rotor blades that enable the aircraft to take off. Unlike fixed-wing aircraft, a helicopter can move in almost any direction with ease and hover in one place. The first operational helicopter took flight around 1936, but the helicopter itself was still under limited production until 1942. One of the first companies to build and sell these aircraft was Sikorsky Aircraft Corporation based out of Stratford, Connecticut. The founder was Igor Sikorsky, an aircraft engineer who had immigrated to the Americas from Ukraine.

Ivan Sikorsky was born in Kiev, Ukraine, in 1889 to Mariya and Ivan Sikorsky. Sikorsky immigrated to the United States in 1919, fleeing the Bolshevik revolution, and founded Sikorsky Helicopter Corporation in 1923. Composer Sergei Rachmaninoff gave Sikorsky \$5,000 to fund his new company. Sikorsky focused on developing more practical helicopters and succeeded in creating an extremely stable helicopter, the Vought-Sikorsky 300. It was the first of its kind, a single-rotor, fully controllable helicopter that would become the model for the vast majority of modern helicopters.

Sikorsky made helicopters for civilian and military use. The Sikorsky R-4 was one of the first helicopters to be mass-produced for military purposes. It employed a new closed cabin, meaning that the inside was completely enclosed; helicopters at the time did not have doors like cars do. This paved the way for modern helicopters, which vary in the number of rotors and number of doors, and, of course, they have improved stability/design.

Aircrafts use a lifting force to fly, using their wings and speed to create lift. However, helicopters use lift force a different way. The blades are their wings, and instead of using speed to take off, the machine uses its blades to move air around the body to create lift. This gives the helicopter some advantages. It does not need speed to create lift force, it has more mobility or freedom in the air, and it can even hover in a single spot while in flight. With these benefits, the helicopter has different practical uses as compared to airplanes. Helicopters are used by hospitals, to help fight fires, on rescue missions, by the military, by the police, and even by the media. Civilians can become licensed to fly helicopters. Companies use helicopters to fly executives short distances.

Military helicopters are used in a variety of ways. Foremost, the military helicopter is modified to be

armored, bulletproof, and outfitted with appropriate communications systems. The American military mainly uses helicopters in the transport of personnel. There are also helicopters made for offensive operations, particularly in anti-vehicle and support positions. They can even be used on reconnaissance missions to observe and gather information.

Helicopters also help civilians, and depending on the area, they have different uses. For example, helicopters can be used to fight fires by dropping off supplies for firefighters or dropping chemicals directly onto fires. They can even be used in rescue missions when a natural disaster occurs and there is no way through the destruction except by air. The most common disasters of this kind are hurricanes and rock- or mudslides. Helicopters are even used by the police force for tracking or just observation. The best example of this is when there is a car chase at night when patrol cars lose visibility. The police helicopter can keep a spotlight on the criminal as long as he or she is in the open, giving the on-the-ground police an opportunity to proceed more safely. The media uses helicopters as well, to cover both news stories and traffic conditions. The National Aeronautics and Space Administration (NASA) uses helicopters to conduct research. It studies crash simulations, the material used to make helicopters, aerodynamics, engine mechanics, and even carrying capacity.

Drones can also be considered a natural progression of helicopter technology. Drones use rotors to fly and hover, but they do so without on-board personnel. This shows how rotor aircraft design is changing in both design and application.

Igor Sikorsky remains a legendary pioneer in aviation technology. His first wife, Olga, chose to remain in Russia after the revolution, and the couple divorced. In 1923, Sikorsky's sister brought his daughter, Tania, to the United States. A year later, Elizabeth Semion married Sikorsky. They had four sons, the oldest of whom worked at Sikorsky Aircraft. Igor Sikorsky died in 1972.

Alan Lopez

See also Avenger Field; B-17 Flying Fortress; Military Technology (World War II); Submarine Technology; Women's Airforce Service Pilots (WASPs)

Further Reading

- Beam, Elwood R. *Helicopter Mechanic (Fully Articulates Rotor) (AFSC 43150C): Helicopter Power Plants and Related Equipment*. Maxwell AFB, AL: Extension Course Institute, Air University.
- Boyne, Walter J. 2011. *How the Helicopter Changed Modern Warfare*. Gretna, LA: Pelican.
- Perritt, Henry H., Jr., and Eliot O. Sprague. 2017. *Domesticating Drones: The Technology, Law, and Economics of Unmanned Aircraft*. New York: Routledge.

Hoover Dam

The Hoover Dam, a massive concrete, arch-gravity dam located in the Black Canyon of the Colorado River on the border between Nevada and Arizona, has been regarded as an engineering marvel with both functional and awe-inspiring design. The government proposed to build the dam to prevent future floods and droughts, which had devastated the area. Once approved, the construction project (1931–1936) employed thousands of workers. The builders contributed hard work and ingenuity to insure the success of the project. Some workers lost their lives.

After the dam was completed, it formed a reservoir (Lake Mead) that insured the year-round availability of water for irrigation and domestic use to all states with water rights. In addition, the dam provided hydroelectric power to the region. In sum, the dam fulfilled the mission that legislators had originally proposed. In fact, the dam's success encouraged legislators to fund other large projects. The dam provided many benefits to the region. However, some environmentalists pointed out that there were costs associated with human tampering with the natural environment. In later years, construction projects failed to eclipse the importance of Hoover Dam as an important American technological achievement.

Especially in western American territories, in the late 1800s, drinking water was the most precious resource. Farmers and ranchers often fought over water rights. In addition, the natural occurrences of floods and droughts caused havoc on both agricultural and cattle enterprises. Long overdue, President

Theodore Roosevelt (1858–1919) signed the Bureau of Reclamation into law in 1902. The Bureau oversaw the sale of public lands in 16 states, and it used the money from the sales to fund various projects. The Bureau's main objective was irrigation (a controlled application of water through human-made systems).

The Keokuk Canal, which had been built in Iowa in 1877, was the first irrigation system to also house a hydroelectric plant on the Mississippi River by 1913. In fact, at that time, the Keokuk hydroelectric plant was the largest in the world. Plants of this type generated electricity by harnessing the flow of falling water to turn turbines. The Keokuk plant and other early plants like it most often used their small amount of electricity themselves. When an excess of electricity was produced, plants sold it and applied the revenue to their own ongoing projects. Sale of electricity on a large scale was not a priority, because it was not the primary purpose of these kinds of projects. However, as the scale of projects (and turbines) increased by the 1920s and 1930s, the sale of electricity to regions of the nation became possible.

Between 1905 and 1907, the Colorado River experienced major floods. The Bureau commissioned a U.S. geological survey of the area to determine an ideal place for a dam. After examining more than 70 sites along the river, the survey team recommended two possibilities: Boulder Canyon and Black Canyon. Other surveys were conducted during the next decade to determine which of these two locations was best, but nothing was built. In 1921, Secretary of Commerce Herbert Hoover (1874–1964) got the project moving again when he recommended that a dam for the Colorado River be built.

In 1924, another survey report stated that Black Canyon was the best spot to build the dam because of its bedrock depth, which would offer greater support. In 1928, the U.S. Congress authorized the Boulder Canyon Project Act for the construction of Boulder Dam in Black Canyon on the Nevada-Arizona line. After Hoover became president in 1929, he continued to support the project. Hoover's supporters made a couple of attempts (in 1929 and in 1930) to name the dam after Hoover, but the bills failed to secure congressional approval. Traditionally, projects were named after the law that made them possible.

According to the Boulder Canyon Project Act, "Boulder Dam" had three main purposes. First, it would provide human control over the river, which would allow engineers to prevent floods. It would also lead to a calmer river that would be much more navigable. Second, the dam would form a reservoir (Lake Mead) that would insure the year-round availability of water for irrigation and domestic use to all states with Colorado River water rights. Third, it would provide hydroelectric power to the region.

Construction on the dam began in 1931, two years after the start of the Great Depression (1929–1939). Many people were desperate for jobs, and, in spite of the dangerous working conditions, the project attracted many workers. In total, 96 workers died on the job, and dozens more died of job-related ailments. Six construction companies (Six Companies) merged to get the massive contract. Before work could begin, crews built Boulder City to house the workers. They also built highways and railroads from the dam site to Boulder City and Las Vegas, Nevada. Once the infrastructure was in place, work on the dam itself began.

First, they diverted the Colorado River through a series of small dams and dynamite-blasted tunnels. According to the plan, after the dam was completed and the river restored to its place, the empty tunnels would then be used to house the electric plant generators. In the meantime, workers dug out more than 382,300 cubic meters (500,000 cubic yards) of mud from the exposed river bed to expose the bedrock, which was located about 40 feet (12 meters) below the surface. While workers below prepared the foundation for the dam, other workers suspended from wires used dynamite to smooth out canyon walls to create a better joining surface with the dam.

Two years later, in 1933, workers began pouring concrete for the dam's base. The concrete pouring process took an additional two years, because workers had to allow time for it to dry properly. The rest of the dam was made up of columns filled with concrete. Engineers knew that concrete released heat when it cooled, and they were concerned that the massive amount of concrete might release so much heat that it might prevent the concrete from setting correctly, which would hurt the integrity of the dam. To compensate, engineers added a concrete cooling system. They

instructed workers to imbed 582 miles of one-inch-diameter pipes in the concrete wall. They then sent ice water through the pipes to cool the concrete as it dried. In total, they poured 230 blocks of concrete (a volume of 3.25 million cubic yards or 2.49 cubic meters).

When it was completed, the dam exceeded the masonry mass of the Great Pyramid of Giza, Egypt. It weighed 6,600,000 tons. According to another estimate, the concrete that was used to build the dam would have been enough to pave a 16-foot (4.9-meter)-wide highway from New York to San Francisco. The magnitude of engineering achievement and size of the project was comparable to the building of the Panama Canal earlier in the century.

In 1935, one year before the work was completed, President Franklin D. Roosevelt (1882–1945), stated the benefits of the dam at a dedication ceremony. Roosevelt sought to align the project with his New Deal agenda of government-run projects designed to help Americans during hardships. He stated that “Boulder Dam” had the ability to prevent floods, to provide irrigation for farmers, and to generate electricity to run factories and provide lighting to residential homes. Roosevelt opposed the idea of naming the dam after Hoover, whom he believed represented anti-New Deal sentiments. (In fact, it was not until two years after Roosevelt’s death that Congress formally adopted “Hoover Dam” as its formal name.) In his speech, Roosevelt wished to provide Americans with hope by pointing out that even during the hardships of the Great Depression, American ingenuity and hard work could accomplish great things.

During the last year of construction, the Colorado River was reverted to its original path and Lake Mead, one of the world’s largest man-made bodies of water, was filled. The reservoir insured the year-round availability of water. The dam provided human control over the river in a way that prevented floods and rendered it navigable. Generators were put in place, and the power plant supplied pollution-free electricity to southern California, Nevada, and Arizona. As a bonus for residents, profits from the sale of electricity were used to fund other projects and therefore reduced their taxes. The success of Hoover Dam prompted government officials to fund other large construction projects.

When the dam was completed in 1936, it stood 726 feet (221 meters) high with a crest width of 1,244 feet (379 meters). Designers went beyond functionality in creating the breathtaking colossal structure. They also included a flair of artistic expression that could be seen in the elegance of its arch-gravity wall, which was a wall with the characteristics of both an arch dam and a gravity dam. The Hoover Dam curved upstream in a narrowing curve that directed most of the water pressure against the canyon walls that, in turn, fortified the dam by compressing it. The total cost of the dam was \$49 million. Internationally, the dam was recognized as an engineering marvel. It was not surprising that Hoover Dam was declared an American historical landmark in 1985. It has remained a popular tourist attraction since it opened. In 1995, dam administrators opened a new visitor center and a new parking structure for the public.

In a more general sense, large works projects like the Hoover Dam that provided a dependable supply of water and electricity often encouraged urbanization, industrialization, and economic growth. Many people were attracted to such areas for construction jobs, and urban centers grew as population grew. After the large work projects were completed, entrepreneurs wishing to establish factories were attracted to these areas by the availability of a large labor force. New factories created more jobs.

Although the Hoover Dam, like other large works projects, created many benefits, some people questioned whether the dam also produced costs, especially to the environment. Studies of the ecosystem (plants and animals in the water habitat) showed that human control of the natural environment had caused changes to the chemical, physical, and biological processes along the Colorado River. Most notably, environmental scientists concluded that the dam had contributed to the decline in population of certain species of fish. Critics of the studies argued that the benefits from Hoover Dam outweighed the costs. They pointed out that human control of the river with the use of the dam had saved thousands of human lives (as well as lives in the ecosystem) from floods and droughts and had contributed greatly to economic development in the region.

In the 1990s, officials began planning a bypass bridge project to alleviate traffic bottlenecks near the

dam. Besides securing funding for the massive undertaking of building a bridge over the Black Canyon, the biggest obstacle was designing a new functional structure that did not detract from the grandeur of the existing landmark. Builders adopted a sleek bridge design with an arched suspension. The construction project began in 2005, was completed in 2010, and was named the Mike O'Callaghan–Pat Tillman Memorial Bridge in honor of a Nevada governor and an Arizona football player who joined the military and died fighting in Afghanistan in 2004.

Visitors to Hoover Dam could see a bridge soaring dramatically across the canyon. In like manner, commuters on the bridge were able to see the dam from a new impressive height and angle. Although some people disliked the addition, others applauded it. In recent years, China's Three Gorges Dam surpassed the massive size of Hoover Dam. Rogun Dam in Tajikistan has also surpassed Hoover Dam's height. However,

Hoover Dam has remained an engineering marvel and an important American icon.

Rolando Avila

See also *Vol. 2, Sec. 2: Hydroelectric Power; Panama Canal*

Further Reading

Arrigo, Anthony F. 2014. *Imaging Hoover Dam: The Making of a Cultural Icon*. Reno: University of Nevada Press.

Dunar, Andrew J., and Dennis McBride. 2001. *Building Hoover Dam: An Oral History of the Great Depression*. Reno: University of Nevada Press.

Hiltzik, Michael. 2010. *Colossus: Hoover Dam and the Making of the American Century*. New York: Free Press.

Stevens, Joseph E. 1988. *Hoover Dam: An American Adventure*. Norman: University of Oklahoma Press.

Primary Document: President Franklin D. Roosevelt's Speech at the Dedication of Hoover Dam (1935)

Hoover Dam was built between 1931 and 1936 on the Colorado River near the Nevada and Arizona border. Although begun under President Herbert Hoover, the dam became part of President Franklin D. Roosevelt's "New Deal for Americans," a plan to put people back to work in the midst of the Great Depression. The following is Roosevelt's speech at the 1935 dedication event for the dam, which Roosevelt called "Boulder Dam."

Senator Pittman, Secretary Ickes, Governors of the Colorado's States, and you especially you have built Boulder Dam, this morning I came, I saw and I was conquered, as everyone would be who sees for the first time this great feat of mankind.

Ten years ago the place where we are gathered was an unpeopled, forbidding desert. In the bottom of a gloomy canyon, whose precipitous walls rose to a height of more than a thousand feet, flowed a turbulent, dangerous river. The mountains on either side of the canyon were difficult of access with neither road nor trail, and their rocks were protected by neither trees nor grass from the blazing heat of the sun. The site of Boulder City was a cactus-covered waste.

the transformation wrought here in these years is a twentieth-century marvel.

We are here to celebrate the completion of the greatest dam in the world, rising 726 feet above the bed-rock of the river and altering the geography of a whole region; we are here to see the creation of the largest artificial lake in the world—115 miles long, holding enough water, for example, to cover the state of Connecticut to a depth of ten feet; and we are here to see nearing completion a power house which will contain the largest generators and turbines yet installed in this country, machinery that can continuously supply nearly two million horsepower of electric energy.

All these dimensions are superlative. They represent and embody the accumulated engineering knowledge and experience of centuries; and when we behold them it is fitting that we pay tribute to the genius of their designers. We recognize also the energy, resourcefulness and zeal of the builders, who, under the greatest physical obstacles, have pushed this work forward to completion two years in advance of the contract requirements. but especially,

we express our gratitude to the thousands of workers who gave brain and brawn to this great work of construction.

Beautiful and great as this structure is, it must also be considered in its relationship to the agricultural and industrial development and in its contribution to the health and comfort of the people of America who live in the southwest.

To divert and distribute the water of an arid region, so that there shall be security of rights and efficiency in service, is one of the greatest problems of law and of administration to be found in any Government. The farms, the cities, the people who live along the many thousands of miles of this river and its tributaries—all of them depend upon the conservation, the regulation, and the equitable division of its ever-changing water supply.

What has been accomplished on the Colorado in working out such a scheme of distribution is inspiring to the whole country. Through the cooperation of the States who people depend upon this river, and of the Federal Government which is concerned in the general welfare, there is being constructed a system of distributive works and of laws and practices which will insure to the millions of people who now dwell in this basin, and the millions of others who will come to dwell here in future generations, a just, safe, and permanent system of water rights. In devising these policies and the means for putting them into practice the Bureau of Reclamation of the Federal Government has taken, and is destined to take in the future, a leading and helpful part. The bureau has been the instrument which gave effect to the legislation introduced in Congress by senator Hiram Johnson and Congressman Phil Swing.

As an unregulated river, the Colorado added little of value to the region this dam serves. when in flood the river was a threatening torrent. In the dry months of the years it shrank to a trickling stream. For a generation the people of the Imperial Valley had lived in the shadow of disaster from this river which provided their livelihood, and which is the foundation of their hopes for themselves and their children. Every spring they awaited with dread the coming of a flood, and at the end of nearly every summer they feared a shortage of water would destroy their crops.

The gates of these great diversion tunnels were closed here at Boulder Dam last February. In June a

great flood came down the river. It came roaring down the canyons of the Colorado, was caught and safely held behind Boulder Dam.

Last year a drought of unprecedented severity was visited upon the West. The watershed of this Colorado River did not escape. In July the canals of the Imperial Valley went dry. Crop losses in that Valley alone totaled \$10,000,000 that summer. Had Boulder Dam been completed one year earlier, this loss would have been prevented, because the spring flood would have been stored to furnish a steady water supply for the long dry summer and fall.

Across the San Jacinto Mountains southwest of Boulder Dam, the cities of southern California are constructing an aqueduct to cost \$220,000,000, which they have raised, for the purpose of carrying the regulated waters of the Colorado River to the Pacific Coast 259 miles away.

Across the desert and mountains to the west and south run great electric transmission lines by which factory motors, street and household light and irrigation pumps will be operated in Southern Arizona and California. Part of this power will be used in pumping the water through the aqueduct to supplement the domestic supplies of Los Angeles and surrounding cities.

Navigation of the river from Boulder Dam to the Grand Canyon has been made possible, a 115-mile stretch that has been traversed less than half a dozen times in history. an immense new park has been created for the enjoyment of all our people.

At what cost was this done? Boulder Dam and the power houses together cost a total of \$108,000,000, all of which will be repaid with interest in fifty years under the contracts for sale of the power. Under these contracts, already completed, not only will the cost be repaid, but the way is opened for the provision of needed light and power to the consumer at reduced rates. In the expenditure of the price of Boulder Dam during the depression years work was provided for 4,000 men, most of them heads of families, and many thousands more were enabled to earn a livelihood through manufacture of materials and machinery.

And this is true in regard to the thousands of projects undertaken by the Federal Government, by the states and by the counties and municipalities in recent years. The overwhelming majority of them are of definite and permanent usefulness.

Throughout our national history we have had a great program of public improvements, and in these past two years all that we have done has been to accelerate that program. We know, too, that the reason for this speeding up was the need of giving relief to several million men and women whose earning capacity had been destroyed by the complexities and lack of thought of the economic system of the past generation.

No sensible person is foolish enough to draw hard and fast classifications as to usefulness or need. Obviously, for instance, this great Boulder Dam, warrants universal approval because it will prevent floods and flood damage, because it will irrigate thousands of acres of tillable land and because it will generate electricity to turn the wheels of many factories and illuminate countless homes.

But can we say that a five foot brushwood dam across the head waters of an arroyo, and costing only a millionth part of Boulder Dam, is an undesirable project or a waste of money? Can we say that the great brick high school, costing \$2,000,000, is a useful expenditure but that a little wooden school house project, costing five or ten thousand dollars, is a wasteful extravagance? Is it fair to approve a huge city boulevard and, at the same time, disapprove the improvement of a muddy farm-to-market road?

While we do all of this, we give actual work to the unemployed and at the same time we add to the wealth of the Nation. These efforts meet with the approval of the people of the Nation.

In a little over two years this work has accomplished much. We have helped mankind by the works themselves, and, at the same time, we have created the necessary purchasing power to throw in the clutch to start the wheels of what we call private industry. Such expenditures on all of these works, great and small, flow out to many beneficiaries. They revive other and more remote industries and businesses. Money is put in circulation. Credit is expanded and the financial and industrial mechanism of America is stimulated to more and more activity.

Labor makes wealth. The use of materials makes wealth. To employ workers and material when private employment has failed is to translate into great national possessions the energy that otherwise would be wasted. Boulder Dam is a splendid symbol of that principle. The mighty waters of the Colorado were

running unused to the sea. Today we translate them into a great national possession.

I might go further and suggest to you that use begets use. Such works as this serve as a means of making useful other national possessions. Vast deposits of precious metals are scattered within a short distance of where we stand today. They await the development of cheap power.

These great government power projects will affect not only the development of agriculture and industry and mining in the sections that they serve, but they will also prove useful yardsticks to measure the cost of power throughout the United States. It is my belief that the government should proceed to lay down the first yardstick from this great power plant in the form of a state power line, assisted in its financing by the government, and tapping the wonderful natural resources of Southern Nevada. Doubtless the same policy of financial assistance to State authorities can be followed in the development of Nevada's sister State, Arizona, on the other side of the river.

With it all, with work proceeding in every one of the more than three thousand counties in the United States, and of a vastly greater number of local division of government, the actual credit of government agencies is on a stronger and safer basis than at any time in the past six years. many States have actually improved their financial position in the past two years. Municipal tax receipts are being paid when the taxes fall due, and tax arrearages are steadily declining.

It is a simple fact that government spending is already beginning to show definite signs of its effect on consumer spending; that the putting of people to work by the government has put other people to work through private employment, and that in two years and a half we have come to the point today where private industry must bear the principal responsibility of keeping the processes of greater employment moving forward with accelerated speed.

The people of the United States are proud of Boulder Dam. With the exception of the few who are narrow visioned, people everywhere on the Atlantic Seaboard, people in the Middle West and the Northwest, people in the South, must surely recognize that the national benefits which will be derived from the completion of this project will make themselves felt in every one of the forty-eight states. They know that

poverty or distress in a community two thousand miles away may affect them, and equally that prosperity and higher standards of living across a whole continent will help them back home.

Today marks the official completion and dedication of the Boulder Dam, the first of four great government regional units. This is an engineering victory

of the first order—another great achievement of American resourcefulness, American skill and determination.

That is why I have the right once more to congratulate you who have built Boulder Dam and on behalf of the Nation say to you, “Well done.”

Source: FDR Presidential Library.

Hydrogen Bomb

Hydrogen bombs derive their power from fusion, which is the same driving force of the sun. Also referred to as thermonuclear bombs, hydrogen bombs force together hydrogen isotopes (deuterium and tritium) to create a blast that is thousands of times more powerful than atomic bombs. By forcing hydrogen isotopes together, the potential amount of energy that can be released by a hydrogen bomb is enormous; some have even described it as limitless.

Hydrogen bombs are a combination of two bombs. For the hydrogen isotopes to be smashed together to start a nuclear chain reaction, a large amount of heat is needed. This necessary heat is obtained from an atomic bomb within the hydrogen bomb. The atomic bomb triggers the hydrogen bomb, and the explosions of each occur almost instantaneously.

Hydrogen bombs have never been used in warfare, but the potential for damage caused by this type of thermonuclear weapon is almost unfathomable. The devastation felt by Japan after the atomic bombs were dropped on Hiroshima and Nagasaki were nothing compared to the destruction that would be caused by a detonated hydrogen bomb. To put its power into perspective, the Nagasaki bomb, the bigger of the atom bombs dropped on Japan, measured 21 kilotons. This is equal to the force of 21,000 tons of TNT. The Tzar Bomb, which was the biggest hydrogen bomb ever detonated, measured 50,000 kilotons. This bomb detonated by Russia was equal to 50,000,000 tons of TNT. That is over 2,300 times more powerful than the bomb dropped on Nagasaki.

The potential dangers and merits of developing a hydrogen bomb were widely discussed and a consensus was ultimately reached that scientists should not

pursue its production. Such development was highly controversial, and many scientists fought against it, including Enrico Fermi and Isidor Rabi. The duo said this of hydrogen bombs: “Since no limit exists to the destructiveness of this weapon, its existence and knowledge of its construction is a danger to humanity as a whole.”

In the early stages of the bomb’s development, President Truman attempted to keep information about it from the public and instructed anyone involved with the project to avoid mentioning it to the press. Word got out, however, and President Truman was forced to announce his decision to move forward with the hydrogen bomb to the American people. Truman stated that he felt there was no alternative to proceeding with the development of atomic weapons, largely because of the Soviet Union’s failed detonation of an atomic device. The arms race between the United States and the Soviet Union was heightened as each country openly began its research and development of hydrogen bombs.

Over the years, several hydrogen bombs have been tested. As of 2016, the United States, Russia, the United Kingdom, China, and France have hydrogen bombs in their possession, making it challenging to attempt to ban nuclear testing and reduce nuclear arms.

Amanda Elaine Duran

See also Fermi, Enrico; *Vol. 3, Sec. 1: Hydrogen Energy*

Further Reading

Holloway, Rachel. 1993. *In the Matter of J. Robert Oppenheimer: Politics, Rhetoric, and Self-Defense*. Westport, CT: Praeger.

Rhodes, Richard. 1996. *Dark Sun: The Making of the Hydrogen Bomb*. New York: Simon & Schuster.

Hydroponics

Hydroponics means “working water,” deriving from the Latin words “*hydro*,” meaning water, and “*ponos*,” meaning labor. Hydroponics is a subset of hydroculture; it is better known as soilless gardening. It is a method of growing plants without soil and feeding them with mineral nutrient solutions, usually in water but not always. Hydroponics provides plants with nutrition and hydration through the flow of oxygen and also water that is nutrient rich. In this system, water goes directly to the roots, where it can be quickly absorbed; but plants need more than just nutrients in this method, such as proper air circulation so that plants can receive carbon dioxide and be protected from mold and bacteria.

The hydroponic method can be used anywhere—inside, outside, or in a greenhouse. With this technique, there are fewer limitations as compared to the “normal” way of planting: plants can be grown in any climate or conditions. This is why hydroponics has become more popular during drastic times.

This method is believed to date back to ancient Rome during the first century CE, when certain minerals were used to grow plants in any season, because the emperor at this time demanded certain flowers to fill his garden. The hydroponics method was used to keep the garden filled year-round. These techniques were used throughout the world in places such as ancient Egypt, Babylonia, China, and also by the Aztecs in Mesoamerica.

However, the technique disappeared and did not reappear until John Woodward began experimenting with it in 1699. He grew mint plants without soil. Woodward’s work would become the foundation of modern hydroponics. The next recorded experiments would not come until 1859 to 1865, when German scientists Julius von Sachs and Wilhelm Knop worked on growing plants with nutrients in a solution.

In the United States, hydroponic work began in 1925, but it was not given this name until 1929, when Dr. F. Gericke achieved success and created a variety of commercial crops without soil. Hydroponics was used during World War II to feed soldiers and is still used today. Hydroponics produces food more easily

because climate is not a factor. Famously, the Disney Company began using a large-scale hydroponic system in its EPCOT (now Epcot) theme park in Orlando, Florida, in 1982. The Disney park uses different methods of hydroponics, including aeroponics and aquaponics; both of these produce amazing crops. Various hydroponic methods are still being discovered.

There are two main methods of hydroponics: solution culture, using only a solution for feeding roots; and medium culture, with a solid medium for roots that is sub or top irrigated and in a container. Many systems of hydroponics have arisen over time. These include the wick system, water culture, the ebb-and-flow system, the drip system, the nutrient film technique (NFT) system, and the aeroponic system.

The simplest is the wick system, which has no moving parts. The plants are submerged underwater, where they receive nutrients. The wick system is efficient, easy, and cheap to maintain. One drawback is that it cannot maintain complex plants; it works well with small ones that need less water, such as lettuce. Another simple system is the water culture system, in which plants are suspended right over the nutrient solution with only their roots hanging in it. Plants get the air and nutrients they need.

The ebb-and-flow system is sometimes known as “flood and drain” and is one of the most widely used methods. Plants are placed in a tray that is periodically filled with nutrient-rich water pumped out of a reservoir, and gravity returns the water to the reservoir to be reused. This method is a little more complex because of its components but it is useful because it can easily support many plants. The drip system is widely used by both homeowners and commercially because it is simple. It is used for large plants that require lots of root space.

The NFT system is similar to the wick and the ebb-and-flow systems. Water is pumped to the grow tray, and a drainpipe is used to recycle the nutrient solution; the nutrient solution flows continuously to the roots with the help of gravity. NFT works best with plants that do not rely much on light. The aeroponic system is much discussed today; it is a high tech method. This system’s growing medium is primarily air; the roots hang in the air and are misted with nutrient solution, directly delivered with no waste. The

system uses only 2 percent of the water that regular gardening does. Many more systems are being developed as well.

The biggest benefit of hydroponics is that plants can be produced all year round instead of in a single season. Studies have shown that this method produces larger harvests, faster. Crops do not take up as much space and can be moved easily. Many other benefits of hydroponics may continue to become apparent.

Claudia Garcia

See also *Vol. 3, Sec. 1: Hydrogen Energy; Vol. 3, Sec. 2: Nuclear Energy/Nuclear Power Plants*

Further Reading

Arma, Teresal, et al. 2015. "Comparison of Cadmium-Induced Oxidative Stress in Brassica Juncea in Soil and Hydroponic Cultures." *Plant & Soil* 388, no. 1/2: 297–305.

International Ladies' Garment Workers' Union (ILGWU)

The International Ladies' Garment Workers' Union (ILGWU) arose during an era when American industry provided few worker protections. In its earliest incarnation, repulsed by the inequality created by unchecked capitalism, the ILGWU turned to socialism to promote a fair future for all workers. Though the ILGWU represents primarily women, men have played a role in its membership and success, and it reached a peak membership of 450,000 in 1969.

Danish American social reformer Jacob Riis (1849–1914) used the term "sweatshop" to describe conditions in the garment industry, where the seven-day workweek, arbitrary hours, and meager pay were the norm in an America where business regulated itself. On March 11, 1900, the United Brotherhood of Cloak Makers' Union No. 1 convened a meeting that created the ILGWU to combat the inequities of sweatshops. Herman Grossman was the union's first president. Jewish women and immigrant women, notably Italian women, were large constituencies of the ILGWU. One of the ILGWU's first acts was to create an education division to increase literacy among immigrant women.

In 1909, the ILGWU participated in the Uprising of 20,000, a 14-week strike against garment employers for improved hours, wages, and working conditions. Strike leader Clara Lemlich demanded that the entire garment industry be shut down by a worker walkout. Female garment workers enthusiastically responded. Employers tried to crush the strike by hiring replacements. The ILGWU could do little to help, having only \$4 in its treasury at the time. The union gained deeper support for its mission of providing safer workplaces after the tragedy of the Triangle Shirtwaist Factory Fire of 1911.

In the 1910s, the ILGWU sought to attract members nationwide, not merely in New York City. As part of its effort to move west, the union sought to organize in Cleveland, Ohio, which was then the nation's fourth-largest center of garment making. The ILGWU members went on strike in 1911 to seek recognition as the sole bargainer for women garment workers. As before, garment shops used scab or nonunion labor and police intimidation to try to break the strike. The ILGWU pointed to the Triangle Shirtwaist Fire in 1911 as evidence of the dangerous and even deadly working conditions under which poor women labored.

In 1914, the ILGWU opened a health clinic, perhaps the first union clinic in the United States. The clinic devoted much of its resources to combating tuberculosis, then an incurable, frightening disease rampant among textile workers because of poor conditions in factories. In the 1920s, many ILGWU women joined the Socialist Party. Tensions between socialists and nonsocialists threatened to divide the union. Socialists within the union wanted to encourage a nationwide revolution by restructuring American government, whereas nonsocialists sought change within the nation's existing political structure.

Despite the Great Depression, the ILGWU was able to negotiate favorable contracts and raise money. The Great Migration of black Americans, most of them poor, from the South to Northern states meant that black women began to work in the garment industry. The ILGWU was initially intolerant of these new workers, in part because racism was not confined to the South and in part because white workers worried about losing their jobs if employers found that they could pay black women even less. As African Americans took

leadership roles, however, they were able to blunt the organization's racism. ILGWU organizer Frank Crossaith formed the Negro Labor Committee to give voice to African American women.

In the 1930s, the ILGWU formed locals in Puerto Rico and Canada. The union supported the New Deal and joined the Congress of Industrial Organization (CIO). The ILGWU was also a member of the American Federation of Labor (AFL) at a time when a union typically joined one or the other but not both. From the outset, the ILGWU believed that the AFL and the CIO should merge, given that a large aggregation of unions would be stronger than many small unions. The ILGWU realized this ambition in 1955 with the merger of the AFL and CIO.

During World War II, the ILGWU opposed the rise of Nazism, fascism, and imperialism in the East. In particular, Italian women in the ILGWU rejected Italian fascist Benito Mussolini (1883–1945). After the war, the ILGWU aimed to help Italy rebuild along democratic lines. As part of the postwar move to the suburbs, the ILGWU funded the construction of new homes for its members.

After the war, the United States moved toward free trade. Third-world economies, clinging to the sweatshop, gained entry into U.S. markets. Cheap imports competed with ILGWU-produced clothes. American clothiers, eager to bypass the ILGWU, moved to Mexico and Asia. The third world could make clothes for about a twentieth of the cost of U.S. union workers. In 1984, wages for garment workers were \$7 per hour in the United States, \$1 per hour in Mexico, 21 cents per hour in China, and 12 cents per hour in Bangladesh. As is often the case, manufacturers put profits ahead of people, and American consumers failed to object to the inequities that this shift

caused, both for American and foreign workers, in part because it encouraged consumer culture with a flood of cheap goods.

These changes in economic policy weakened the ILGWU. By 1994, membership had declined to 125,000. This trend is part of a larger story in which the number of garment workers in the United States has declined, wages have flattened, and imports have flooded the domestic market, allowing retailers to increase their markups and consumers to buy more disposable goods.

By the late 20th century, New York City estimated that some 3,000 garment makers did not pay minimum wage, forcing the U.S. Department of Labor to try to collect more than \$2.3 million in lost wages for 8,000 workers. Immigrants from Latin America and Asia have taken jobs in the garment industry, creating further downward pressure on wages. Recently a move toward educating American consumers about the dangers to workers, combined with environmental realities caused by cheap and plentiful consumer goods, has begun to address these issues. Nonetheless, worker abuses and deaths in overseas garment factories in the 21st century suggest that much remains to be done.

Christopher Cumo

See also *Vol. 1, Sec. 3: Sewing Machine, Automated; Vol. 2, Sec. 1: Lady Stitchers' Union; National Consumers League*

Further Reading

Ross, Andrew. 1997. *No Sweat: Fashion, Free Trade, and the Rights of Garment Workers*. New York: Verso.
Tyler, Gus. 1995. *Look for the Union Label: A History of the International Ladies' Garment Workers' Union*. Armonk, NY: M. E. Sharpe.

Primary Document: "The Uprising of the 20,000"

The New York Shirtwaist Strike of 1909, also called "The Uprising of the 20,000," set the standard for female labor organizing in the early 20th century and for garment industry unions. The strike, featured in the song here, contributed to the ILGWU's rapid growth in the 1910s.

The Uprising of the Twenty Thousand
Dedicated to the Waistmakers of 1909

In the black of the winter of nineteen nine,
When we froze and bled on the picket line,

We showed the world that women could fight
And we rose and won with women's might.

Chorus:

Hail the waistmakers of nineteen nine,
Making their stand on the picket line,
Breaking the power of those who reign,
Pointing the way, smashing the chain.

And we gave new courage to the men
Who carried on in nineteen ten
And shoulder to shoulder we'll win through,
Led by the I.L.G.W.U.

Source: *Let's Sing!* Educational Department, International Ladies' Garment Workers' Union, New York City, n.d.

Interstate Highway System

The interstate highway system both represented and fueled the changing patterns of life and work in the post–World War II United States. A model of federalism, an example of the federal and state governments working together, the American highway system was a network of integrated major highways that still allows motorists to travel easily about the country. It is a system that both represents the impact of the automobile on American society and serves to further enhance the centrality of the car in American life.

Substantive interest in some kind of expansive, coordinated national system of highways in the United States can be traced back to the mid-1920s. Initial talk of coordinating existing state networks led to discussions about the creation of a true national system. These preliminary discussions reflected the increased use of the automobile as well as the nation's growth and changing demographics. And, as the Great Depression deepened, the job creation potential of such a project added to its political appeal. However, at their most advanced stage, the early discussions focused only on three east-west and three north-south routes. With the passage by Congress of the Federal-Aid Highway Act of 1938, formal consideration of a federally coordinated system, however limited its reach, began. Under that law, the Bureau of Public Roads (BPR) was directed to study the feasibility of such a six-route toll network. The BPR report, *Toll Roads and Free Roads*, was submitted to Congress in 1939, and although it concluded that such a system could not be self-supporting and instead urged a less extensive network, it represented the first formal concept of an interstate highway system. While the nation's increasing

mobilization for World War II put many things on the back burner, in 1941, President Franklin Roosevelt appointed a National Interregional Highway Committee and named BPR head Thomas MacDonald as chairman. The group's 1944 report refined the earlier Interstate Highway concept, and in response, Congress took the step that, earlier forays notwithstanding, marked the start of the modern system, passing the Federal-Aid Highway Act of 1944, a law that authorized construction of a 40,000 mile "National System of Interstate Highways" intended to connect the nation's cities. The plan also included the establishment of an additional system of principal secondary and feeder roads.

In reality, this legislation was something of a false start, for it included no funding mechanism. Instead, it was intended to serve as a statement, a reflection of a national commitment, with states expected to make highway construction a top-priority item on their lists for spending federal aid funds. However, with numerous other postwar needs, states devoted few funds to road construction.

The first funding for the national highways came in legislation enacted in 1952. That law, the Federal-Aid Highway Act of 1952, authorized a paltry \$25 million a year for the fiscal years 1954 and 1955. The law also called for a 50-50 state/federal matching funding plan. The Federal-Aid Highway Act of 1954 upped the nation's investment considerably. This version raised the authorization to \$175 million a year while changing the federal-state ratio to 60-40. However, all of this paled in comparison to the legislation passed in June 1956, when, after years of political maneuvering, Congress passed a new version of the Federal-Aid Highway Act. This version dedicated

\$26 billion to financing the 41,000 miles of highway that were intended to go from coast to coast. The funding was to come from a tax on each gallon of gas, and the federal government would foot the bill for 90 percent of the highway creation. To protect the fund, and recognizing that the project would not end with the building of the road but that maintenance would be necessary, the Federal-Aid Highway Act of 1956 that authorized the construction and the spending was aided by the enactment of the Highway Revenue Act of 1956, which was not technically a separate piece of legislation but rather a supplemental one that contained the funding mechanism by which the user taxes would be set aside for future highway purposes. The legislation, sponsored by Louisiana Democratic congressman Hale Boggs, established a Highway Trust Fund that was modeled on the Social Security Trust Fund. Reflective of the Congressional and administration cooperation that characterized the effort, the trust fund idea had been a suggestion of Eisenhower's Treasury secretary, George Humphrey.

In addition to authoring the construction of an interstate highway network as well as a mechanism for the funding, the 1956 act established national standards for design. Among these were a minimum of two lanes in each direction. The lanes themselves had to be at least 12 feet wide with a 10-foot right-side paved shoulder. They were also intended to accommodate speeds of 50 to 70 miles per hour; these high speeds were intended to eliminate congestion. There were to be no at-grade crossings—only over- and underpasses to facilitate both safety and speed. The goals of these efforts were to make coast-to-coast travel easier, facilitate city evacuation in case of atomic attack, and replace slums with more attractive “ribbons of concrete.”

The government's support of this national network of highways made their construction easier and fueled a national building boom. The boom was not limited to the highways. Rather, the increased highway mileage contributed to a major change in the nation's residential and housing development patterns, accelerating the already developing shift to the suburbs.

When John Kennedy came into office in 1961, the system developed funding issues. In 1959, President Eisenhower signed into legislation to raise the federal gas tax to pay for the Interstate System. When the tax

was set to expire in 1961, President Kennedy asked Congress to make the tax permanent.

While the future existence of the system was assured, the Kennedy administration had to turn its attention to some of the developing and previously unanticipated objections that had started to emerge. One problem involved charges of corruption. While investigators found that allegations far exceeded reality, such charges undermined public support at a time when the Kennedy administration was making a concerted effort to develop greater public awareness and appreciation for the magnitude and importance of the project to the American economy and way of life. Arguing that each completed interstate highway was the best advertisement the system could offer, the states were urged to keep building in pursuit of the established goals.

While the early responses to the developing network had generally been positive, with the whole system being the beneficiary of widespread public support, as the idea moved from concept and plans to reality, its impact on neighborhoods and cities led to some protests and second thoughts. Indeed, especially problematic was the impact that the new highways sometimes had on local neighborhoods and cities. Organized opposition increasingly emerged as more and more homeowners were displaced and neighborhoods were split in half by the introduction of highways. In a growing number of cases, the result of the introduction of an interstate highway was the abandonment of some part of a city. Active efforts were made to defeat or alter plans, and in some cases, there was success. Evidence of those efforts can be seen today in places where the interstate ends abruptly, resulting in what some critics derisively termed “roads to nowhere.”

In response to the opposition, under Kennedy, new regulations were adopted that called for the Commerce Department to be involved in reviewing issues relating to the displacement of families and businesses. In addition, greater relocation payments were provided. Finally, in a nod to the challenges that came from meshing new highways with the nation's existing urban settings, the Federal-Aid Highway Act of 1962 required that the planning cooperate with local stakeholders.

Another unanticipated obstacle to the developing network was the emerging environmental movement, one fueled by the September 1962 publication of Rachel Carson's *Silent Spring*. While the book dealt

with no issues related to the Interstate System, it opened the public's eyes to the way that human actions impacted the environment, and such a connection was soon made with the ongoing interstate construction and local citizens. Indeed, highway engineers whose previous marching orders had focused on finding the best traffic routes at the lowest cost and with the least disruption of residential area and business districts were suddenly forced to consider the potential environmental impact of their efforts. In fact, in August 1963, BPR issued a directive that, beginning on January 1, 1964, states had to certify that they had considered the potential impact on fish and wildlife of any new Federal-Aid Highway project.

The next step in the ongoing interstate highway system saga came in 1963 with the passage of the Federal-Aid Highway Act of 1963. Although the bill featured little more than technical changes, it did include one provision that reflected the growing size and impact of the system. Whereas the original 1956 legislation had called on highway engineers to design roads capable of meeting the traffic demand in 1975, concern about the system soon becoming obsolete led to a provision in the 1963 act calling for a design that would carry the project 20 years into the future.

While the process had become more complicated and the factors affected by each mile of completed highway had grown, the project continued toward completion, stretching to the far corners of the nation, north and south, east and west, throughout the 1960s and into the 1970s. Subsequent legislation has expanded the original plan, creating new routes in places previously ignored as the nation's demographics have changed.

The importance of a national highway system caused Congress to create the Department of Transportation in 1966 with its secretary, one of whose

major responsibilities was the oversight of the Interstate System, joining the presidential cabinet. Too, its reach was highlighted in another way when First Lady "Lady Bird" Johnson sought to beautify the nation by prohibiting billboard advertising along the interstates. However, the initiative had only limited and short-lived success as the captive audience provided by the thousands of miles of landscape and the millions of passing drivers/consumers was too strong a commercial force to allow for a total prohibition.

In 1990, in acknowledgment of the critical role he played in the development of the system, legislation was enacted that officially designated the system the Dwight D. Eisenhower System of Interstate and Defense Highways.

With the formal framework fully established and the funding in place, the progress toward completion continues. With the familiar three-digit beltways that circle the nation's major urban areas, routes that can take travelers through a succession of states, and the almost 43,000 miles of highway that it includes, the U.S. Interstate Highway System is a reflection of a people that is at once independent and interdependent but always on the move.

William H. Pruden III

See also *Vol. 1, Sec. 3: Railroads; Vol. 2, Sec. 2: Automobile Technologies (Pre–World War II); Petroleum Industry (Pre–World War II); Vol. 3, Sec. 1: Automotive Technologies (Post–World War II); Petroleum Industry (Post–World War II)*

Further Reading

Pfeiffer, David A. 2006. "Ike's Interstates at 50: Anniversary of the Highway System Recalls Eisenhower's Role as Catalyst." *Prologue Magazine* 38, no. 2 (Summer).

Primary Document: Excerpt from the Federal-Aid Highway Act (1956)

Though most Americans no longer remember this, the Interstate Highway System was proposed and built, in part, to aid in national defense. Post–World War II politicians, in the midst of a Cold War with the Soviet Union, believed it was essential that the nation be able to swiftly move the military and its supplies around the nation by way of a highway system. The

following is an excerpt of the Federal-Aid Highway Act of 1956, signed into law by President Dwight D. Eisenhower.

Enrolled Acts and Resolutions of Congress, 1789–1996; General Records of the United States Government; Record Group 11; National Archives

Sec. 108. National System of Interstate and Defense Highways.

(a) Interstate System. It is hereby declared to be essential to the national interest to provide for the early completion, of the National System of Interstate Highways, as authorized and designated in accordance with section 7 of the Federal-Aid Highway Act of 1944 (58 Stat. 838). It is the intent of the Congress that the Interstate System be completed as nearly as practicable over a thirteen-year period and that the entire System in all the States be brought to simultaneous completion. Because of its primary importance to the national defense, the name of such system is hereby changed to the National System of Interstate and Defense Highways. Such National System of Interstate and Defense Highways is hereinafter in this Act referred to as the Interstate System.

(b) Authorization of Appropriations. For the purpose of expediting the construction, reconstruction or improvement, inclusive of necessary bridges and tunnels, of the Interstate System, including extensions thereof through urban areas, designated in accordance with the provisions of section 7 of the Federal-Aid Highway Act of 1944 (58 Stat. 838), there is hereby authorized to be appropriated the additional sum of

\$1,000,000,000; for the fiscal year ending June 30, 1957, which sum shall be in addition to the authorization heretofore made for that year, the additional sum of \$1,700,000,000 for the fiscal year ending June 30, 1958, the additional sum of \$2,000,000,000 for the fiscal year ending June 30, 1959, the additional sum of \$2,200,000,000 for the fiscal year ending June 30, 1960, the additional sum of \$2,200,000,000 for the fiscal year ending June 30, 1961, the additional sum of \$2,200,000,000 for the fiscal year ending June 30, 1962, the additional sum of \$2,200,000,000 for the fiscal year ending June 30, 1963, the additional sum of \$2,200,000,000 for the fiscal year ending June 30, 1964, the additional sum of \$2,200,000,000 for the fiscal year ending June 30, 1965, the additional sum of \$2,200,000,000 for the fiscal year ending June 30, 1966, the additional sum of \$2,200,000,000 for the fiscal year ending June 30, 1967, the additional sum of \$1,500,000,000 for the fiscal year ending June 30, 1968, and the additional sum of \$1,025,000,000 for the fiscal year ending: June 30, 1969.

Source: Federal-Aid Highway Act of 1956. Enrolled Acts and Resolutions of Congress, 1789–1996; General Records of the United States Government; Record Group 11; National Archives.

Lamarr, Hedy (1914–2000)

More than a Hollywood star, Hedy Lamarr was one of the most influential female inventors of the 20th century. She invented spread spectrum technology, the basis for worldwide wireless communication systems.

Born Hedwig Eva Maria Kiesler to upper-middle-class Jewish parents in Vienna, Austria, Lamarr was always intrigued with how things worked. Acting courses, however, led to her discovery by German theater producer/director Max Reinhardt, and she began acting professionally at age 17. As Hedy Kiesler, she appeared in several German and Czech films, including *Ecstasy* (1933). She became infamous as the “Ecstasy girl” for depicting the first on-screen orgasm. The film was banned in the United States, and Lamarr was labeled sexually provocative.

The same year, Lamarr rocketed to international notoriety, and she married wealthy armaments manufacturer Fritz Mandl. As a member of the Austrian fascist movement, Mandl entertained both Italian dictator Benito Mussolini and the new German chancellor, Adolf Hitler, at his estate. Lamarr was expected to play hostess. Mandl frequently took her to high-level German military meetings. She listened in on discussions regarding engineering challenges for a submarine torpedo guidance system.

One night in 1937, Lamarr escaped both Mandl and Nazi Germany by disguising herself as her maid and fleeing to Paris. After a meeting in London with Louis B. Mayer, head of MGM studios, Lamarr signed a film contract to work in Hollywood. To distance her from her “Ecstasy girl” image, Mayer changed her name to Hedy Lamarr and demanded morality clauses

in her contract. Once in the United States, her divorce was finalized, and she arranged for her mother to join her in California.

In 1940, early in World War II, German submarines began torpedoing civilian ships. Remembering the flaws in the German torpedo systems, Lamarr determined to contribute to the war effort. She theorized that if a communication transmission could be bounced randomly from one radio frequency to another, it would be impossible to intercept, decode, or jam the communication. However, she was challenged by how to synchronize the randomly changing frequencies between both the sender and the receiver of the communication.

Lamarr met avant-garde composer and pianist George Antheil in Hollywood. Antheil, the son of German immigrants, had composed *Ballet mécanique* using synchronized player pianos. With the rise of the Nazi Party, he fled Germany. The two combined Lamarr's idea of frequency hopping with a mechanism similar to a roll on a player piano. Lamarr and Antheil filed for and received a patent for a "Secret Communications System" in August 1942.

Lamarr and Antheil offered their invention to the U.S. Navy but were rebuffed. Officials may have been biased against an idea created by two Hollywood entertainers, one of them a famous female actor. Lamarr also offered to participate on the National Inventions Council to aid the war effort but was advised that she could accomplish more using her celebrity to raise funds selling war bonds. She went on to raise \$7 million for the war effort in a single evening.

Lamarr's invention of frequency hopping, or spread spectrum technology, sat unused for decades. The patent expired in 1960. In 1962, technological advances in microprocessors made frequency hopping feasible, and the technology was used to secure American military radio transmissions during the Cuban Missile Crisis. Today, U.S. defense communication satellites, cellular phones, the Global Positioning System (GPS), and other wireless communication systems all employ Lamarr's technological invention. The technology is also used in integrated bar code scanners, handheld computers, computer data, and e-mail.

During her Hollywood film career, Lamarr appeared in over 20 movies. She felt that her beauty and



Though Hedy Lamarr is best remembered as a film actress of the 1930s and 1940s, she was also a talented inventor. The frequency hopping technology she developed in 1942 is now used in Bluetooth and Wifi technologies. (Sunset Boulevard/Corbis via Getty Images)

early notoriety had caused her to be cast as an immoral vixen. The fixation on her physical beauty over her intellect may also have sabotaged her self-image; she was married and divorced six times. She continued inventing throughout her life—a kind of traffic light, a fluorescent dog collar, modification ideas for the supersonic Concorde plane, and more.

Neither Lamarr nor Antheil received any financial benefit from their invention. In 1997, Lamarr and Antheil received the Electronic Frontier Foundation Pioneer Award, and Lamarr became the first woman to receive the BULBIE Gnass Spirit of Achievement Award (a lifetime achievement award for inventors). Lamarr was inducted into the National Inventors Hall of Fame in 2014, and throughout German-speaking countries in Europe, Inventor's Day is celebrated on her birthday, November 9. Lamarr died in 2000.

Keri Dearborn

See also Wu, Chien-Shiung; *Vol. 2, Sec. 1*: Harvard Computers; Jones, Amanda T.; Richards, Ellen Swallow; *Vol. 2, Sec. 2*: Anderson, Mary; Blodgett, Katherine; Cannon, Annie Jump; Dickerson, Mary Cynthia

Further Reading

Rhodes, Richard. 2011. *Hedy's Folly: The Life and Breakthrough through Invention of Hedy Lamarr, the Most Beautiful Woman in the World*. New York: Doubleday.

Primary Document: Patent for Hedy Lamarr's Frequency-Hopping System (1942)

On June 10, 1941, famed Hollywood actress Hedy Lamarr and composer George Antheil were granted a patent for a frequency hopping system to be used in torpedo guidance systems. Though many sources claim that Lamarr invented frequency hopping, Nikola Tesla had done the original work on frequency hopping some 40 years earlier. Lamarr and Antheil's innovation was to use frequency hopping in a new way. Lamarr, who was known for a time as "the most beautiful woman in the world," invented a number of things in her life, including a new kind of soda pop.

This invention relates broadly to secret communication systems involving the use of carrier waves of different frequencies, and is especially useful in the remote control of dirigible craft, such as torpedoes.

An object of the invention is to provide a method of secret communication which is relatively simple and reliable in operation, but at the same time is difficult to discover or decipher.

Briefly, our system as adapted for radio control of a remote craft, employs a pair of synchronous records, one at the transmitting station and one at the

receiving station, which change the tuning of the transmitting and receiving apparatus from time to time, so that without knowledge of the records an enemy would be unable to determine at what frequency a controlling impulse would be sent. Furthermore, we contemplate employing records of the type used for many years in player pianos, and which consist of long rolls of paper having perforations variously positioned in a plurality of longitudinal rows along the records. In a conventional player piano record there may be 88 rows of perforations, and in our system such a record would permit the use of 88 different carrier frequencies, from one to another of which both the transmitting and receiving station would be changed at intervals. Furthermore, records of the type described can be made of substantial length and may be driven slow or fast. This makes it possible for a pair of records, one at the transmitting station and one at the receiving station, to run for a length of time ample for the remote control of a device such as a torpedo.

Source: United States Patent Office. Secret Communication System. U.S. Patent 2292387, August 11, 1942.

Lange, Dorothea (1895–1965)

Documentary photographer Dorothea Lange is known primarily for the work she did on assignment during the Great Depression with the Resettlement Administration/Farm Security Administration from 1935 to 1939, taking pictures of poor and disadvantaged Americans. Lange was prolific throughout her life despite the pressures of marriage, divorce, motherhood, disability, and recurring illness. Photographer Lange took pictures for the Resettlement Administration as part of the New Deal program's efforts to

record the damage that the Great Depression and Dust Bowl did to Americans. Her *Migrant Mother* picture is one of the most famous photos in American history.

Born Dorothea Margareta Nuthorn in 1895 and raised in Hoboken, New Jersey, Lange suffered from polio at the age of seven, which resulted in a lifelong limp. Her father, Henry Nuthorn, abandoned the family when she was 12. Her mother, Joanna "Joan" Caroline Lange, became a librarian to support the family, bringing Lange, who would take her mother's maiden name as her surname, with her on the ferry to attend school on the Lower East Side of Manhattan. Her

father's abandonment and her exposure to the cultural and economic diversity of Manhattan influenced her worldview and her work.

Lange began studying photography in New York City when she was 17. She apprenticed with photographer Arnold Genthe. In 1918, she and her friend Florence Bates left on a trip around the world and made it as far as San Francisco. Lange would live in nearby Berkeley for the rest of her life.

Lange opened a photographic studio in San Francisco in 1919. She was successful as a portraitist for elite-class clientele. In 1920, she married Maynard Dixon, a well-known painter. They had two sons. They traveled together, but Lange discovered that his career took precedence over hers. They began living separately and ultimately divorced after 15 years of marriage.

When the Great Depression began in 1929, Lange felt guilty about the disparity between the wealthy patrons sitting for portraits in her studio and the masses of struggling and jobless Americans. She left her studio and took her camera out into the world. What resulted over the next decades were some of the most iconic and memorable photographs of the 20th century: the *White Angel Breadline*, the instantly recognizable *Migrant Mother*, and Lange's work on many other projects in the western and southern United States as well as in Ireland, the Middle East, and elsewhere.

In 1935, Lange married Paul Schuster Taylor, an economist. Their work dovetailed often, as he studied agriculture under the auspices of the State Emergency Relief Administration (SERA). He hired Lange to photograph the pea harvest in Nipomo, California. She was subsequently hired by the Information Division of the Farm Security Administration (FSA, first known as the Resettlement Administration), run by Roy Stryker, to photograph the living conditions of migrant workers, many of whom had been displaced by poverty or the Dust Bowl in the Midwestern and Southern United States. Her photographs of America's poorest citizens reminded the nation of the dangers of a country with no social welfare safety net and a poorly regulated economy.

In 1942, at the beginning of World War II, Lange was hired by the War Relocation Authority to photograph the relocation of Japanese Americans to internment camps. Together with Ansel Adams, she

photographed the people and living conditions of the entire relocation process before finishing up with work at Manzanar. Her photographs are a stark protest of the cruelty and immorality of the relocation program. Indeed, the photographs proved to be too good and were impounded by the U.S. Army for decades in an effort to hide what they contained.

In 1940, Lange was the first woman to be awarded a Guggenheim Grant, a program that provided promising artists the funds to live for a year and make art. The war interrupted her proposed project, but she took up the work again after the war ended, photographing Mormon communities with her son Daniel Dixon in collaboration with her friend and fellow photographer, Ansel Adams.

Lange struggled with health problems throughout her life, some exacerbated by her bad leg and limp. She considered herself disabled but also considered it a boon in her career, saying that her disability made people nicer to her and more likely to let her photograph them.

Diagnosed with cancer of the esophagus in 1965, Lange spent her last months assembling her life's work for her retrospective at the Museum of Modern Art and helping with a documentary about her life. The exhibition at the Museum of Modern Art in New York opened in 1966, three months after Dorothea Lange died in Berkeley, California.

Robin Potter

See also Lamarr, Hedy; Rosie the Riveter

Further Reading

Gordon, Linda. 2009. *Dorothea Lange: A Life beyond Limits*. New York: Norton.

Lend-Lease Program (1941–1945)

The Lend-Lease Act allowed the United States to provide arms, supplies, and financial assistance to the Allies during World War II (1939–1945). Allied defeat in Europe was probable without U.S. aid, yet President Franklin D. Roosevelt's administration deemed the Act necessary in the face of strong American isolationist tendencies. Although the Act had been originally

developed to aid Great Britain, by the end of the war, 38 nations had received more than \$50 billion of aid. American factories transitioned from making consumer goods to churning out plentiful and innovative war materials, which helped turn the tide of the war.

The Great Depression (1929–1939) devastated the U.S. economy. Many banks and businesses failed, and many Americans lost their jobs and homes. In the 1930s, the Dust Bowl (soil erosion caused by drought and strong winds), which swept through several states, including Texas and Oklahoma, multiplied the hardships faced by farmers. These present troubles, coupled with the memory of American casualties during World War I (1914–1918), reinforced American isolationist tendencies. Consequently, the rise of dictators in Europe and Asia and even the start of World War II did not sway most Americans, who felt that they had enough troubles of their own to contend with. Such was the overwhelming sentiment that U.S. politicians promised constituents that they would see to it that the Atlantic and Pacific Oceans would isolate the United States from other nations' problems.

In 1940, the British prime minister convinced President Roosevelt that Britain would fall to Germany without U.S. aid. Roosevelt believed that a strong Britain was crucial for U.S. security. Britain could not build ships fast enough to keep up with Germany's effective use of submarine technology; consequently, Roosevelt decided to circumvent a series of 1935 Neutrality Acts. In late 1940, Roosevelt issued an executive order to transfer 50 old American destroyers to Britain in exchange for 99-year leases on air and naval bases. Although the United States was still officially neutral, the ships-for-bases deal was the first step away from genuine American neutrality. In early 1941, Roosevelt asked Congress for the power to sell, exchange, lend, or lease war equipment to any nation that was vital to U.S. defense (without a U.S. declaration of war), and Congress granted his request with the Lend-Lease Act.

Before and after the United States officially entered the war in late 1941, many nations benefited greatly from the great quantities of available war materials. For example, the United States provided the Soviets with more than 100,000 railcars and 20,000 aircraft. By the last year of the war, two-thirds of all

Soviet supply trucks were being made in U.S. factories. The Act was also responsible for the availability of innovative war materials. For example, by the end of the war, Allied ships had onboard sonar and radar equipment, which were used to effectively combat German submarine warfare. Besides greatly contributing to Allied victory, one major legacy of the Act was a postwar U.S. economic boom.

Rolando Avila

See also Military Technology (World War II)

Further Reading

Stettinius, Edward R. 1944. *Lend-Lease: Weapon for Victory*. New York: Macmillan.

Liberty Ships

The “liberty ship” is the name given to the emergency cargo carrier ship manufactured by the U.S. Maritime Commission for use during World War II. The emergency fleet program was an assembly-line production of consistently reliable ships. Liberty ships were nicknamed “ugly ducklings” by President Franklin Delano Roosevelt, but they served their purpose.

Liberty ships were made to meet with British orders for transport ships to replace those destroyed by the German U-boats. In 1941, the steam turbine engine was chosen for these ships because it was more productive than prior steam engines. The ships were assembled of sections welded together. The SS *Patrick Henry* was the first of 2,710 liberty ships launched in 1941; it had taken 150 days to build. The SS *Robert E. Peary* was assembled in four days, 15 hours, and 29 minutes.

The U.S. Navy tested a number of liberty ships in the North Atlantic. Three ships developed cracks severe enough to break into two parts, while 1,500 other ships developed small hull fractures. Yet, more than 2,400 liberty ships endured the war. Of the 2,400, 835 made up the postwar cargo fleet, and 200 disappeared during World War II due to accidents and battles.

Originally, liberty ships were made to last up to five years, but some still sail today. Two are active: the SS *Jeremiah O'Brien* in San Francisco, California, at Pier 45 on Fisherman's Wharf; and the SS *John W.*

Brown in Baltimore, Maryland. Both are open for the public to tour. In 2011, the United States Postal Service issued a set of Merchant Marine stamps, one of which was a liberty ship.

Lorrie Mae Panis

See also Bradberry, Henrietta; Lamarr, Hedy; Military Technology (World War II); *Vol. 1, Sec. 2: Gas Tungsten Arc Welding*; *Vol. 2, Sec. 1: Iron Ship with Revolving Turret*; *Vol. 2, Sec. 2: Automobile Technologies (Pre–World War II)*

Further Reading

- Borden, Louise, and Michael Foreman. 2003. *The Little Ships: The Heroic Rescue at Dunkirk in World War II*. New York: Aladdin.
- Cooper, Sherod. 1997. *Liberty Ship: the Voyages of the John W. Brown, 1942–1946*. Annapolis, MD: Naval Institute Press.
- Elphick, Peter. 2006. *Liberty: The Ships That Won the War*. London: Chatham.
- Sandvick, Gerald N. 2017. *World War II Shipbuilding in Duluth and Superior*. Mount Pleasant, SC: Arcadia.

M&M's

A classic, iconic American candy with a hard shell and chocolate filling inside, the M&M was first introduced in the 1940s and is now distributed in over 100 countries. Its inventor, Forrest Mars, conjured up the idea in the 1930s upon witnessing soldiers eat hard-shelled candies called “smarties,” which were made from saccharine or syrup. He then further developed his own formula that used milk chocolate instead of syrup. He patented his candy with the hard shell and milk chocolate filling in 1941.

The company used the hard candy shell feature in its advertising campaign, which said, “The milk chocolate melts in your mouth—not in your hand.” This appealed to soldiers and parents equally. In the 1950s, the company introduced an M printed on the hard shell, which became a well-recognized trademark. In the 1980s, M&M's began their international journey to countries such as Australia, Canada, the United

Kingdom, Europe, Hong Kong, and Japan. Peanut M&M's were introduced in the 1950s and almond M&M's in the 1960s. Almond M&M's were taken off the market soon after their introduction and not reintroduced until the 1980s. In the 1990s, M&M's introduced peanut butter–filled M&M's, crispy M&M's, and M&M minis. In the 2010s, the company introduced pretzel M&M's, caramel M&M's, and the M&M chocolate bar.

Sohel Poojani

See also D Rations

Further Reading

- Brenner, Joel Glenn. 2000. *The Emperors of Chocolate: Inside the Secret World of Hershey and Mars*. New York: Broadway Books.

M4 Sherman Tank

The M4 Sherman tank was broadly used throughout all theaters of war in World War II. It was the first American tank to incorporate a 360-degree mounted turret. In its final version, the tank was released into war with a 75mm gun, and the engine that drove the tank was a Continental R975 engine, which was air-cooled and produced 400 horsepower. Steering was by a dedicated driver positioned with a frontal view, either through a front hatch when out of combat or through a small, cutout slit in the armor.

Production of the Sherman medium tank started in February 1942. Further testing was conducted on the M4 under the Steel Car Company and the Pacific Car and Foundry Company. After testing, the M4 was dubbed combat worthy and given the new name M4A1. The United States then produced 6,281 of them with the 75mm gun. The main difference between the M4 and the M4A1 is that the M4 has a welded, angular upper hull, which can store more gun shells—97 versus the 90 of the M4A1.

If the Sherman tank received a direct hit, its engine often would explode. This warranted it a few nicknames, such as “the Burning Grave” or “Tommy Cooker.” This created a distrust in the gasoline-driven M4 as opposed to its diesel counterparts. Further research determined that the propellant charges for the

ammunition were the problem. It was found that red-hot enemy projectiles that pierced the turreted gun ignited the propulsion charges, causing a chain reaction of explosions, sometimes blowing the turreted gun off altogether. This was fixed quickly with additional armor to combat penetration of the turret, and the ammo once stored in the turret was moved down into the main hull, where large steel plates protected it.

The M4 was quickly modified into different variants for carrying different loads of weapons, all the way up to howitzers. New turrets were put in place, as were new engines, giving the tank more power to trek through mud and other obstacles. Furthermore, a new suspension system was added in 1944, allowing the tank to absorb more energy upon firing weapons and from the impact of shells on its armor. This improved the longevity of the tank.

The M4 Sherman tank was first used by the British at the Second Battle of El Alamein in October of its production year. A month later, the Americans used the M4 at Operation Torch landings, the invasion of North Africa. Antitank teams of the Axis forces downed many a tank in the European and African theaters. The M4 had a better time dealing with the Japanese antitank teams in the Pacific theater, as their weapons were less devastating.

Production of the M4 Sherman tank continued after the end of World War II, and so a plethora of tanks was ready when the Korean War broke out. But more efficient tanks had been developed by this time, so the M4 took a back seat to the new developments and acted as a second line of defense during the war. Once the war was over, the M4 was used as a basis to develop the improved M46 and 47 Patton, which would eventually replace the M4, which was retired in 1957.

Nathaniel C. Cooley

See also Military Technology (World War II); *Vol. 2, Sec. 1: Iron Ship with Revolving Turret*

Further Reading

Hunnicut, R. P. 1978. *Sherman: A History of the American Medium Tank*. Brattleboro, VT: Echo Point Books and Media.

Zaloga, Steven J. 2013. *M4 (76mm) Sherman Medium Tank 1943–65*. Oxford: Osprey.

Manhattan Project

World War II brought many horrors of war the likes of which had never been seen before. Some occurred because of the scientific research and development intended to assist with the war effort, including the Manhattan Project, which designed and constructed the world's first-ever nuclear weapon.

The Manhattan Project was officially established in 1942 by the U.S. Army, though it had essentially begun in 1939. At its start, the project's funding was only \$6,000 annually, but by the end of it, it had cost an estimated \$2 billion, not accounting for inflation. The Manhattan Project had also employed up to 130,000 by the end of its operation. The project gained most of its traction when it was discovered that German scientists were working on similar projects involving nuclear fission, which set a tone of extreme urgency for the United States to compete.

By 1943, the U.S. government was cooperating with Canada and England on the effort, and the Manhattan Project remained active until it was disbanded on August 15, 1947, having been partially replaced by the U.S. Atomic Energy Commission.

Prior to the creation of the project, two Hungarian physicists, Leo Szilard and Eugene Wigner, drafted a letter expressing concern that the Axis forces were developing an extremely dangerous new bomb. President Franklin D. Roosevelt then set in motion the gathering of nuclear material and invested in the nuclear research of Enrico Fermi. The S-1 Committee, which considered the letter's concerns, met in October 1939 and concluded that uranium could yield some of the most destructive weapons the world had ever seen. In December 1941, after the attack on Pearl Harbor, the S-1 Committee met again. War was declared upon the Axis forces.

The key nuclear fissile materials for the bomb project were uranium-235, uranium-238, and plutonium-239. U-235 had to be separated from the more plentiful U-238. Robert Oppenheimer worked with Robert Serber to examine the neutron diffusion and hydrodynamics of the expected explosion. Italian physicist Enrico Fermi, who had come to the United States in 1938 to avoid discrimination against his Jewish wife, met with Oppenheimer and other leading theoretical physicists in the summer of 1942 to discuss the

theoretical possibility of the fission bomb. Oppenheimer assumed the role of director for the Los Alamos Laboratory where design concepts for the bomb were being developed.

As the Manhattan Project grew, so did the size and workload of the Los Alamos Laboratory. After years of testing designs for the weapon, Oppenheimer finalized one in early 1945. With the culmination of the project's work nearing, an interim committee was created to advise about future wartime and postwar use of nuclear energy.

The infamous first test of the bomb was known as Trinity and was executed on July 16, 1945, at an airbase about 100 miles south of Albuquerque, New Mexico. The bomb was set on the top of a steel tower and was observed by scientists and dignitaries alike from several bunkers many miles away. The news of the weapon's functionality was then given to President Truman at the Potsdam Conference in Germany, where he then told Stalin of the newfound superweapon. Truman authorized the use of the bomb just as the Japanese rejected the Potsdam Declaration, allowing the horrific act to be set in motion.

Only a few days later, the superweapons known as "Little Boy" and "Fat Man" were dropped upon Hiroshima and Nagasaki respectively. Upon the enactment of the nuclear attacks, the Manhattan Project had achieved completion of its sole objective and would soon disband.

Evann W. Conditt

See also Atomic Bombs/Nuclear Weapons; D Rations; Gas Mask; Liberty Ships; Military Technology (World War II); MIT Radiation Laboratory; Oppenheimer, J. Robert; Radar; Rocketry (Pre-Space Age); Schwinger, Julian; SONAR; Submarine Technology

Further Reading

- Cimino, Al. 2016. *The Manhattan Project: The Making of the Atomic Bomb*. London: Arcturus.
- Kelly, Cynthia C., and Richard Rhodes. 2010. *The Manhattan Project: The Birth of the Atomic Bomb in the Words of Its Creators, Eyewitnesses, and Historians*. n.p.: Tess Press.
- Rhodes, Richard. 2012. *The Making of the Atomic Bomb: The 25th Anniversary Edition*. New York: Simon & Schuster Paperbacks.

Mead, Margaret (1901–1978)

Among the world's most renowned cultural anthropologists, Margaret Mead was a perceptive commentator on a wide range of world cultures, including that of the United States. Like her mentor, American anthropologist Ruth Benedict (1887–1948), Mead wrote for the layperson as well as for scholars. In this sense, she was a public intellectual. She was to cultural anthropology what British anthropologist Louis S. B. Leakey (1903–1972) was to physical anthropology: an accomplished scholar of worldwide fame. Throughout her career, Mead addressed myriad topics: nuclear energy, abortion, breastfeeding, civil disobedience, euthanasia, and premarital sex. In her eagerness to address the layperson, Mead wrote a monthly column for *Redbook* from 1965 until her death in 1978. Mead also addressed the public through radio, television, and cinema. She could be controversial, as when she advocated for the legalization of marijuana. Her popularity and her gender seem to have caused some anthropologists to resent her.

The oldest of five children, Margaret Mead was born December 16, 1901, in Philadelphia, Pennsylvania, to Edward Sherwood and Emily Fogg Mead, both distinguished academics. Though her parents were agnostic, Mead at age 11 sought baptism in the Episcopal Church and seems to have remained devout throughout her life. Mead attended DePauw University for one year before transferring to elite Barnard College in New York City. There she became engaged to theology student Luther Cressman. Declaring a major in psychology, Mead took an anthropology course in her senior year and met American anthropologists Franz Boas (1858–1942) and Ruth Benedict (1887–1948). Under Benedict's influence, Mead decided to pursue a career in anthropology. Mead graduated from Barnard College and married Cressman in 1923, next pursuing a master's degree in psychology at Columbia University. Boas encouraged Mead, like Benedict, to study Native American cultures, but Mead chose Samoa, a Polynesian island, where she began fieldwork on female adolescence in 1925. Mead's research led to the publication of *Coming of Age in Samoa*, where she cataloged Samoan women's frank promiscuity and lack of guilt about sex.



Cultural anthropologist Margaret Mead studied Pacific Islanders and, unlike those before her, resisted applying Western values to non-Western people. Her work suggested that Western standards about sex, gender roles, and child rearing were not natural, but culturally constructed. (Library of Congress)

From her research, Mead believed that culture determined people's ideas about women and, by extension, about men. Later investigators found that Samoans had "hoaxed" Mead by lying to her about their sexual practices.

Returning to New York City, Mead became assistant curator of ethnology at the American Museum of Natural History. In 1929, she earned her PhD in anthropology from Columbia University. Despite her duties, Mead took occasional leaves of absence to teach at Yale University, Vassar College, New York University, Emory University, and Columbia University. Mead sought to promote interdisciplinary studies in education, social work, psychology, sociology, psychiatry, and pediatrics. In the 1930s, Mead broadened her research to New Guinea, where she focused on

children, and to Native American cultures, where she studied gender issues, again arguing that culture, not biology, shapes gender roles. Hard-line hereditarians disagreed with Mead, seeing biology as the determinant of sex roles. During these years, Mead had several lovers. Because she was bisexual, some of her liaisons were with women. With her third husband, Mead had a daughter, her only child.

During World War II, Mead arranged a leave of absence from the museum to become executive secretary of the National Research Council Committee on Food Habits. The fact that the United States might have to ration food during the war gave Mead's assignment special urgency.

As she aged, Mead spent less time in the field, but her work continued to influence American culture.

Mead's examinations of the sexual habits of a number of cultures informed many Americans' ideas about sex during the counterculture of the 1960s. Second-wave feminists disagreed about Mead. Some women saw in Mead a powerful role model, while others, notably Betty Friedan (1921–2006), argued that the inaccuracy of Mead's early work had done women a great disservice.

Her awards included 28 honorary degrees from universities worldwide, the Viking Medal in anthropology, and the Presidential Medal of Honor. During her lifetime, she presided over the American Anthropological Association, the American Academy for the Advancement of Science, the World Federation of Mental Health, and the Society for Applied Anthropology. She published 44 books, 18 of them coauthored, and more than 1,000 articles and reviews. In 1978, the *World Almanac* named her one of the world's 25 most influential women. The Library of Congress holds her papers. Margaret Mead died November 15, 1978.

Christopher Cumo

See also *Vol. 3, Sec. 1:* Goeppert-Mayer, Maria; McClintock, Barbara; *Vol. 3, Sec. 2:* Fossey, Dian

Further Reading

- Bowman-Kruhm, Mary. 2003. *Margaret Mead: A Biography*. Amherst, NY: Prometheus Books.
- Gordon, Robert, Andrew P. Lyons, and Harriet D. Lyons. 2011. *Fifty Key Anthropologists*. London: Routledge.
- Lutkehaus, Nancy. 2011. *Margaret Mead: The Making of an American Icon*. Princeton, NJ: Princeton University Press.

Microwave Oven

Microwave ovens are appliances now found in almost every American household. They are popular because they are so convenient, heating food quickly by using thermal energy.

Microwave technology is attributed to physicist Percy Spencer (1894–1969). Spencer discovered the power of microwaves accidentally: he was testing a magnetron when he noticed that a chocolate bar in his pocket had melted. He realized that the magnetron was

emitting microwaves capable of heating food. This led him to create the “Radarange” in 1946, a refrigerator-sized metal box into which a magnetron would send microwaves to heat food. The first Radaranges cost several thousand dollars and were used primarily by commercial kitchens. By the 1950s, smaller Radaranges were developed for home use but cost upward of \$1,295, more than most American families could afford.

In the 1970s, improvements in magnetron technology led to smaller, cheaper-to-manufacture microwave ovens. This trend has continued, and today, many consider microwaves essential kitchen appliances.

Alberta M. Miranda

See also *Vol. 1, Sec. 3:* Compact Iron Stove; Electric Stove

Further Reading

- Metaxas, A. C. 1996. *Foundations of Electroheat: A Unified Approach*. New York: Wiley.
- Petroski, Henry. 2003. *Small Things Considered: Why There Is No Perfect Design*. New York: Alfred A. Knopf.

Military Technology (World War II)

While wars are waged on the battlefield, in the skies, or on the waves, they are often won or lost on drawing boards, proving grounds, or in laboratories. Technology, whether in the form of high-energy foods or nuclear power, can spell the difference between military victory and defeat. The military technologies developed during World War II were no exception. Although some were improvements over World War I technologies, other innovations during the later conflict were made to counteract those being deployed by one side or another. By 1945, military technology had become the signature of World War II, so much so that it became known as the first war where military operations widely targeted enemy research efforts. It was also a struggle in which scientists, physicists, mathematicians, and engineers became commodities, leading one observer to conclude that the Allied victory over fascism had been a result of the quality of the scientific community that each side possessed. In an arena in

which measures and countermeasures followed hard on each other's heels and where change was the only constant, World War II truly gave new meaning to Plato's assertion that necessity is the mother of invention.

Advancements in weapons clearly demonstrated just how much of an impact technology would have on World War II. Nothing was left untouched, from the weapons that men carried into combat to the devices that would carry men into combat. Semiautomatic weapons gave way to portable, fully automatic ones. Open-cockpit aircraft were eventually replaced by sleeker, more aerodynamic, canopied models. Bombers would, by war's end, employ technology that would allow them to fly farther, be less vulnerable to attack, and deliver their payloads more accurately. Even battleships, which had been the gold standard in naval warfare during World War I, had by 1945 been neutralized and perhaps even rendered obsolete by the advent of aircraft carriers. The battleship's earlier nemesis, the submarine, had already been partially defanged by sonar, a military technology that used sound waves to seek out and help destroy them.

For every technological measure introduced during World War II to help one side or the other turn the tide, there was a response waiting just around the corner to stem it. German tanks terrorized Allied forces during the war, but once the United States and Britain began building and deploying tank destroyers that fired armor-piercing shells, tanks became vulnerable. As aerial bombardment became more effective, new responses on that front were deployed. Radar, an acronym for "radio detection and ranging" technology, helped spot aircraft. Once radar had fixed an enemy plane's location and altitude, antiaircraft artillery would be trained on the target, firing radar-directed proximity-fuse shells. They didn't have to achieve a direct hit; the shells just had to get high enough and close enough to detonate, and they let the exploding shrapnel do the rest. To escape antiaircraft fire, planes had to increase altitude, and this meant that crew members risked oxygen deprivation until cabins could be pressurized. The altitude also meant that bombing accuracy was jeopardized until more accurate targeting technologies, such as the Norden bombsight, were developed. Of course, military technology was showing signs that human involvement in war might soon be passé. Ordnance that

reduced human involvement began to appear during the latter stages of the conflict. Germany produced the first generation of smart bombs followed by the V-1, the world's first cruise missile, and later the V-2, the first ballistic missile weapon. On a more modest, yet equally lethal level, precision-guided munitions such as magnetic torpedoes and aiming devices for machine guns using special-purpose mechanical and electronic digital systems would further distance humans from harm's way. Of course, the ultimate technology that drew a line in the sand separating some humans from war was atomic power. The invention of the atomic bomb meant that a single aircraft could carry a weapon sufficiently powerful to devastate entire cities. The aftermath of the atomic bombings of Hiroshima and Nagasaki meant an end to World War II—and an end to any doubts about technology's role in conflict.

But military technology during World War II wasn't all about bombs and bullets. Armies needed to eat to fight, so dieticians were enlisted to help find the vitamins and minerals that a body needed to stay healthy and cope under stressful situations. Studies were commissioned to find out how many calories were consumed during combat training, and theories were constructed about how many more calories a man might need in actual combat. The food a soldier carried was designed to give him the most nutrition and energy while still managing to taste good. C Rations provided a number of meat dishes and desserts. D Rations, typically used in emergencies, were small, high-calorie, high-energy chocolate bars. The army said it couldn't taste too good for fear that soldiers would eat them instead of saving them for a more appropriate time. So the chocolate that soldiers carried was designed by science to be good but not tasty. M&M's just tasted good. The chocolate candy, which, as most people know, "melts in your mouth and not in your hand," was the result of a collaboration between the Mars and Hershey candy companies. The beady chocolates were sold to the military when the United States entered World War II and were used as an easy way to provide troops with chocolate on the battlefield.

Military technology also ventured into the realm of medical technology. While penicillin had been invented before the war, the technology to mass-produce it came into existence during the fighting,

which made it available to millions of people around the world. Medicines against diseases like malaria also became critical for the United States in its fights in tropical climates like the South Pacific. Pesticides like DDT played an equally critical role in killing mosquitoes. And there was more evidence of military technology influencing not only the way the war was fought but even the lives of civilians.

Plastic wrap, known to some by the trademarked name “Saran Wrap,” became a substitute for aluminum foil for covering food. Cardboard milk and juice containers replaced glass bottles, and plywood emerged as a substitute for scarce metals and was used for everything from the hulls of PT boats to aircraft wings. Speaking of aircraft, pilots who had to bail out of their damaged planes no longer “hit the silk,” a term used to describe the deployment of a parachute. Japan’s occupation of the silk-producing regions of Asia sent scientists scurrying to find a replacement. The answer was nylon, a synthetic fiber that would soon show up in automobile tires, since the war had also cut off America’s access to rubber. Coincidentally, nylon also began showing up on the legs of American women. Deprived of silk stockings, they had resorted to shading their legs with makeup and drawing lines up the backs of their legs to complete the illusion that they were wearing seamed stockings. Nylon hosiery saved the day, not to mention the American woman’s sense of fashion under adverse conditions.

Some have referred to World War II as the first total war and the first high-tech war. Jet planes, radar, sonar, and DDT, to mention but a few, were all technological devices designed for waging war. Many of those innovations found uses after the shooting stopped. DDT’s uses in peacetime proved environmentally disastrous. But not everyone immediately connects the rise of computers to the war effort. The reality is that many of society’s most significant technological achievements were made in the midst of one of society’s most destructive events. But if necessity is indeed the mother of invention, then war has had to figure greatly in that process.

John A. Morello

See also Avenger Field; B-17 Flying Fortress; Big Science; D Rations; Freeze-Dried Food; Gas Mask; Helicopter; Lamarr, Hedy; Liberty Ships; M4 Sherman

Tank; Oppenheimer, J. Robert; Plastic Wrap; SONAR; Submarine Technology; Women’s Airforce Service Pilots (WASPs); Wu, Chien-Shiung

Further Reading

- Everett, H. R. 2015. *Unmanned Systems of World Wars I and II: Intelligent Robotics and Autonomous Agents Series*. Cambridge, MA: MIT Press.
- Jenkins, Ryan. 2014. *World War II: New Technologies that Affected WWII Warfare*. CreateSpace.
- Kennedy, P. 2013. *Engineers of Victory: The Problem Solvers Who Turned the Tide in the Second World War*. New York: Random House.

MIT Radiation Laboratory

The MIT Radiation Laboratory, also known as “Rad Lab,” was an independent laboratory at the Massachusetts Institute of Technology (MIT) in Cambridge, Massachusetts, staffed by civilian and academic scientists from every discipline and operated from October 1940 until December 1945. It played a crucial role in U.S. military research and development during World War II, especially in developing the microwave radar (radio detection and ranging) system.

Before World War II, a practical application of microwave radar had not been developed. The British government requested help from the U.S. National Defense Research Committee (NDRC) to develop this proficiency. President Franklin Roosevelt approved the research, and the project commenced. The Rad Lab developed the first worldwide radio navigation system called Loran-A (or Loomis Radio Navigation, a.k.a. “LRN”) and was responsible for developing most of the microwave radar technology used by the United States during World War II.

Radar works by transmitting electromagnetic waves and analyzing the reflecting echo off an object. Since the discovery of radar, it has found many uses, such as detection and identification of objects’ velocity, range, and direction. But it was not until a scientist invented an oscillator that using radar to detect objects from airplanes many miles away was possible in World War II. The British government focused on developing practical applications for airborne microwave radar in

response to the threats and impact of German drones and submarines. It had had no way of detecting German V-1 drones and German U-boats from a distance.

In 1940, before the United States entered World War II, Britain partnered with the NDRC to develop microwave radar systems. Vannevar Bush, the scientific advisor to President Franklin Roosevelt and head of the U.S. Office of Scientific Research and Development (OSRD), worked with his colleague, Karl Compton, the president of MIT, and James Conant, president of Harvard, to create a plan to present to President Franklin Roosevelt for the NDRC to do this. Roosevelt quickly approved, since he felt this would help the Allied forces to win the war.

Karl Compton led the council's oversight of technologies that could detect objects from a distance. The task was quickly narrowed to detection using microwave, with Alfred Loomis, a wealthy American scientist and head of the NDRC Microwave Committee, developing a device. Loomis's committee's promising results found that microwaves could theoretically work. In October 1940, Compton and Loomis selected MIT as the site of the radiation laboratory that would build magnetrons and research microwave electronics. The Rad Lab officially opened in November 1940 as the approved joint effort between U.S. and British scientists.

During World War II, most air and naval combat was fought with radar in the UHF range and below. Following the attack on Pearl Harbor and the entry of the United States into the war, the work at Rad Lab expanded, focusing research on physical electronics, microwave physics, electromagnetic properties of matter, and microwave communication principles. One of the most notable microwave radars that the lab developed was the SCR-584, a widely used gunfire control system. It was first used in combat early in 1944 on the Anzio beachhead in Italy. This radar caught the Germans unprepared.

The MIT Rad Lab closed operations in December 1945. It had employed more than 4,000 people working on several continents and had spent close to \$4 million per month. It had industrialized over 100 radar systems, and its designs resulted in \$1.5 billion of radar production in industry. Its innovations, organization, and equipment contributed to the creation of MIT's Research Laboratory of Electronics (RLE).

During the five years of its operations, the MIT Radiation Laboratory made significant contributions to development of microwave radar technology in support of the war effort. Its inventions included the H2X radar used for aiming bombs, a shipboard search radar, harbor and coastal defense radars, gun-laying radars, ground-controlled approach radars for aircraft blind landings, interrogate-friend-or-foe beacon systems, and the long-range navigation (loran) system.

Some of the most critical contributions of the MIT Radiation Laboratory were the microwave early-warning (MEW) radars, which effectively nullified the German V-1 drone threat to London, and air-to-surface vessel (ASV) radars, which turned the tide on the German U-boat threat to Allied shipping. Aircraft equipped with ASV radars destroyed a total of 25 German U-boats. The fundamental contributions to the design and deployment of microwave radar systems played a decisive role in the Allied victory. All of the people who worked there made very important and lasting contributions to microwave theory and technology, operational radar, systems engineering, long-range navigation, and control equipment in the United States.

Rosanne Welch

See also Manhattan Project; *Vol. 3, Sec. 3*: Negroponte, Nicholas

Further Reading

Alvarez, Luis W. 1983. "Alfred Lee Loomis—Last Great Amateur of Science." *Physics Today* 36, no. 1: 25.

APS Physics. <https://www.aps.org/programs/outreach/history/historicsites/mit.cfm/>, accessed August 29, 2018.

Engineering and Technology History (ETWH). http://ethw.org/Milestones:MIT_Radiation_Radiation_Laboratory,_1940-1945, accessed August 29, 2018.

Lincoln Laboratory. <https://www.ll.mit.edu/about/History/RadLab.html/>, accessed August 29, 2018.

Neoprene

Neoprene (chloroprene) is a commonly used synthetic rubber with elasticity as opposed to rigidity in its resin. Elmer Keiser Bolton first developed the

chemical. He was the research director at DuPont at the time. Using the research of chemists before him, he aimed to polymerize the brittle versions of existing acetylene plastics. Hydrogen chloride gas and monovinyl acetylene reacted to form chloroprene, which, when left to sit polymerized into polychloroprene.

This substance was found to bounce when dropped, and it was resistant to UV radiation that caused the degradation of most plastics. It was then renamed Duprene, since it had been developed at DuPont; later, it was renamed to “neoprene.” Neoprene is most commonly used in wet suits. The low density of the structure makes it light and helps it maintain pliability in direct sunlight. Some other common uses today are in laptop sleeves and Halloween masks.

Plastics have a negative effect on the environment, and neoprene is not exempt from this. Weather balloons are made from neoprene, and they can pop at altitude, landing in bodies of water or elsewhere. Since neoprene was developed to resist degradation, it remains as pollution for years before it begins to degrade. Animals may ingest it, which can have devastating effects on their health.

Nathaniel C. Cooley

See also *Vol. 1, Sec. 3: Vulcanization; Vol. 2, Sec. 2: Bakelite*

Further Reading

Crawford, Christopher B. 2017. *Microplastic Pollutants*. London: Elsevier B. V.

Nuclear Weapons. See Atomic Bombs/
Nuclear Weapons

Oppenheimer, J. Robert (1904–1967)

J. Robert Oppenheimer was a pioneer of American theoretical physics, significant for his research in the areas of astrophysics, spectroscopy, and quantum field theory. He is primarily remembered as the “father” of the atomic bomb. As the head of the Manhattan Project, he helped develop the world’s first nuclear weapon in 1945.

Born in New York City in 1904, Oppenheimer grew up in a well-to-do family. His father was a

successful German textile importer, and his mother was an artist. The family was Jewish but religiously nonobservant.

Oppenheimer studied physics at Harvard and graduated *summa cum laude* in 1922, having completed his degree in three years. He was then accepted at Cambridge to work in the Cavendish Laboratory, a placement that confirmed his suitability for theoretical rather than experimental physics. In 1926, Oppenheimer left Cambridge to study under Max Born at the University of Göttingen, developing the Born-Oppenheimer approximation, the assumption that the motions of atomic nuclei and electrons in a molecule can be separated. He received his PhD in physics in 1927. Oppenheimer then embarked on teaching, serving concurrently on the faculties of the University of California, Berkeley and the California Institute of Technology beginning in 1928.

In 1942, Oppenheimer was invited to be part of the Manhattan Project, the secret program tasked with actualizing the newly developed fission process involving uranium-235 into a nuclear weapon. He initially was assigned to work on fast neutron calculations, and he brought together a group of his own students and European physicists to UC Berkeley for a crash course in bomb theory. Later in the year, Oppenheimer was appointed the scientific director of the Manhattan Project’s secret weapons laboratory. He had a key role in the selection of the site for the centralized secret research laboratory at Los Alamos, New Mexico. After three years of development and refinement, the atomic bomb was tested on July 16, 1945, in the first artificial nuclear explosion that took place near Alamogordo, New Mexico, a site that was codenamed “Trinity.” Soon after this test, an atomic bomb was dropped on the Japanese city of Hiroshima, which Oppenheimer viewed as a triumph. However, the subsequent bombing of Nagasaki did not meet with Oppenheimer’s approval, because he did not feel that this bombing was militarily necessary. Oppenheimer resigned from the Manhattan Project later that year after witnessing the destruction caused by the atomic bomb. He was awarded the Medal for Merit for his role as director of Los Alamos by President Harry S. Truman in 1946.

From 1947 to 1952, Oppenheimer served as the chairman of the General Advisory Committee to the

Atomic Energy Commission, during which time he advocated for international arms control. Oppenheimer voiced his opposition to the development of the hydrogen bomb in 1949, a stance that was politically fraught and which may have led to accusations of his being a communist. Due to suspicions of his being sympathetic to the communist cause, Oppenheimer's security clearance was revoked in 1953. In 1963, President Lyndon B. Johnson presented him with the Atomic Energy Commission's Enrico Fermi Award, an award perhaps bestowed in an attempt to compensate for this affront.

From 1947 to 1966, Oppenheimer served as director of Princeton's Institute for Advanced Study in Princeton, New Jersey. The mission of this Institute was to bring together academics from multiple disciplines to solve the world's pressing issues. During this time, Oppenheimer focused on research in quantum and relativistic physics.

In 1960, motivated by what he saw as the growing danger to humanity that could result from scientific discoveries, Oppenheimer founded the World Academy of Art and Science with Albert Einstein, Bertrand Russell, and Joseph Rotblat. Oppenheimer died of throat cancer in 1967.

Terry Steagall

See also Atomic Bombs/Nuclear Weapons; Manhattan Project

Further Reading

- Bird, Kai, and Martin J. Sherwin. 2006. *American Prometheus: The Triumph and Tragedy of J. Robert Oppenheimer*. New York: Doubleday.
- Monk, Ray. 2014. *Robert Oppenheimer: A Life Inside the Center*. New York: Doubleday.

Paul, Les (1915–2009)

Les Paul was a guitarist and inventor who pioneered multitrack sound recording. Lester Polfuss was born on June 9, 1915, in Waukesha, Wisconsin. An inveterate tinkerer throughout his life, Les Paul amplified his guitar as a youngster by sticking a phonograph needle into it attached to a radio speaker. After starting out in country music as "Red Hot Red" and "Rhubarb Red,"

he established himself as a jazz performer in the 1930s under the name Les Paul. He performed with some of the biggest names of the day, both as a soloist and with his trio, including Fred Waring's Pennsylvanians, the Andrews Sisters, and Bing Crosby, with whom he was featured on the number-one hit single, "It's Been a Long, Long Time" (1945).

Paul worked hard to improve the sound of both his instrument and his recordings. Acoustic guitars lacked the volume to solo alongside brass instruments, so magnetic pickups were added to amplify them. Paul made his own pickups and used electrified archtops, which he referred to as "clunkers," but vibrations from their hollow bodies interfered with vibrations from the strings. Believing that a solid-body guitar would eliminate the distortions, Paul designed "the Log" in 1941, which was a four-by-four-inch block of wood to which he attached a Gibson neck, an Epiphone fretboard, and two pickups. He then added two halves of an Epiphone guitar to the block so it looked like a traditional guitar. Neither Gibson nor Epiphone were interested in manufacturing it.

Paul built a recording studio in his garage and began to experiment with multitrack recording (which he called "sound on sound"), which was painstakingly done on wax disks by playing along with one disk while recording onto a second one. He also used delay, echo, close miking, reverb, phasing, and flanging. Paul's "new sound" debuted on the song "Lover" (1948), which featured his overdubbed electric guitar on multiple parts, some of which were recorded and played back at different speeds. After Crosby gave him an early Ampex tape recorder, Paul immediately added a fourth head, which enabled him and second wife Mary Ford to play and sing along with what had been recorded on the first take as it was recorded as a new track on the same tape.

This also enabled them to make recordings away from their studio. Paul later was involved with Ampex in the development of the first eight-track recording system. The couple had 28 hits between 1950 and 1957, including "How High the Moon" and "Vaya con Dios," all of which featured overdubbing of Paul's guitar and Ford's voice, making it sound like they were accompanied by an ensemble. They also produced their own television show from 1953 to 1960. To recreate their multitracked songs in live performances,



Blues guitarist and luthier Les Paul is famous for his innovations in solid body electric guitars, recording technology, and playing style. He is the only person in both the Inventor's Hall of Fame and the Rock and Roll Hall of Fame. (Library of Congress)

Paul built a device he named the “Les Paulverizer” to control backstage tape equipment from onstage.

The success of the Fender Telecaster convinced Gibson to manufacture a solid-body guitar, and they brought a prototype to Paul for his endorsement. The Gibson Les Paul was released in 1952, and it would become a favorite of many rock musicians. Ironically, Paul and Ford's recordings became less popular as music tastes changed and young people embraced rock 'n' roll, which was based on the electric guitar that Paul had long championed.

Among Paul's many honors were three Grammy Awards (1977, 2006), a Grammy Trustees Award (1983), the James Smithson Bicentennial Medal (1996), a Grammy Technical award (2002), the Emmy Lifetime Achievement Award (2004), the Sammy Cahn Lifetime Achievement Award from the Songwriters

Hall of Fame (2005), and the National Medal of Arts (2007). Paul and Ford's recording of “How High the Moon” was inducted into the Grammy Hall of Fame (1979), and Paul was inducted into the Rock and Roll Hall of Fame (1988), the National Inventors Hall of Fame (2005), and the Broadcasting Hall of Fame (2006). He died on August 13, 2009, at age 94.

John A. Drobnicki

See also Electric Guitar

Further Reading

Paul, Les, and Michael Cochran. 2016. *Les Paul: In His Own Words*. Milwaukee, WI: Backbeat Books.

Shaughnessy, Mary Alice. 1993. *Les Paul: An American Original*. New York: William Morrow.

Waksman, Steve. 2010. “Les Paul: In Memoriam.” *Popular Music and Society* 33, no. 2: 269–73.

Penicillin

Penicillin is an antibiotic that can bring a wide range of bacterial infections under control within a relatively short time. Before its discovery, medical treatments for infections were ineffective and dangerous. Alexander Fleming (1881–1955) discovered the antibiotic properties of a penicillium spore due to an unintended petri dish contamination. Howard Florey (1896–1968), Ernst Chain (1906–1979), and their team of researchers turned Fleming's lab accident into a life-saving drug. During World War II (1939–1945), Allied leaders expedited the mass production of penicillin to make it available for the treatment of wounded troops. After the war, penicillin was made available to the civilian population. Since that time, researchers have expanded the number of available antibiotics based on penicillin's chemical composition. Although penicillin has some drawbacks, it has revolutionized modern medicine and saved many lives.

In ancient times, doctors used maggot therapy to treat flesh wounds. As maggots fed on dying flesh, they excreted antibacterial substances that helped fight infection. However, these doctors had no effective tools against internal infections. In the 18th and 19th centuries, doctors often treated patients with internal infections with laxatives or by bleeding them with the aim of flushing out body toxins. Both treatments often made matters worse. Since the Middle Ages, doctors used toxins to reduce the symptoms of syphilis, but there was no known cure.

In the 1930s, German doctors used sulfa drugs to reduce bacterial infections. Unfortunately, many patients experienced side effects from sulfa drugs ranging from rashes to kidney failure. In 1929, Fleming was working on a routine bacteriology experiment at St. Mary's Hospital in London. While sorting through some petri dishes, he noticed that a dish bearing colonies of staphylococcus was growing a stray mold, which had contaminated the dish by accident. After further experimentation, he noticed that the mold was able to kill bacteria. Fleming, who was awarded the Nobel Prize in 1945 for his discovery, had no interest in investigating its medical benefits.

In 1939, Florey, Chain, and their team of researchers at Oxford University made penicillin available to

the pharmaceutical industries in both Great Britain and the United States during the same year that World War II broke out in Europe. As a consequence, the life-saving drug remained in Allied hands during the war while the Axis powers had to do without it. According to historians, penicillin saved many Allied lives and may have ultimately contributed to Allied victory.

After the war, civilians enjoyed the benefits of penicillin, which was regarded as a miracle drug due to its dramatic results. The astounding benefits of penicillin encouraged scientists to conduct future research with molds, and they developed various antibiotics that could treat different bacterial infections. Since some people are allergic to certain drugs, the availability of different drug choices is beneficial.

Once researchers isolated the antibacterial chemical components in penicillin, they were able to create a semisynthetic version of penicillin in 1957. Semisynthetic penicillin is much more effective than naturally occurring penicillin, because it is more resistant to breakdown when in contact with gastric acids in the stomach. However, all penicillin-related drugs have two major shortcomings. First, penicillin cannot cure virus-related illnesses such as the common cold. Although proven vaccines for some virus-related illnesses exist, in most cases, people must combat life-threatening virus-related illnesses with nothing but their own immune systems. Second, bacteria can mutate and become resistant to antibiotics.

For this reason, doctors must exercise caution in prescribing penicillin, because overuse is the biggest factor that leads to resistance. If bacteria mutations should outpace available drugs, the world will once again be at the mercy of bacterial infection as it was before the discovery of penicillin. Additionally, antibiotics have had an undesirable side effect on hospital environments. In some fatal cases, resistant bacteria have attacked patients with compromised immunities. In spite of these drawbacks, penicillin has remained invaluable. Approximately 45,000 tons of penicillin-related antibiotics are produced worldwide every year. Compared to medical options in previous centuries, the discovery of penicillin was a tremendous technological leap forward.

Rolando Avila

See also *Vol. 3, Sec. 1: Antibiotic; Vaccines*

Further Reading

Brown, Kevin. 2005. *Penicillin Man: Alexander Fleming and the Antibiotic Revolution*. Stroud, UK: Sutton.

Tames, Richard. 2006. *Penicillin: A Breakthrough in Medicine*. Chicago: Heinemann Library.

pH Meter

The pH meter is a scientific invention that measures the acidity or alkalinity in water-based solutions. The pH meter was created in October 1934 by American inventor Arnold Orville Beckman. Beckman is credited with registering the first patent on a complete chemical apparatus for the measurement of pH, which he originally named the “acidimeter.”

The pH meter generally consists of a voltmeter (an instrument used to measure electric potential in volts) attached to a pH-responsive electrode and a reference electrode (this is unvarying for reference). The voltmeter measures the electric potential when the electrodes are placed inside the solution, acting as a battery since the two electrodes need a medium to run current between the two electrodes to determine the acidity or alkalinity on the pH scale of 0 to 14.

PH meters can be as simple as pen-like devices or a complex piece of machinery that can refine the accuracy of the measurements, including temperature and volume. PH meters now also come with solid-state electrodes in lieu of conventional liquid-state electrodes to use in soil or other mediums.

Jose D. Avelar

See also Photocopier; Radar

Further Reading

Kenkel, John. 2010. *Analytical Chemistry for Technicians*. 3rd. ed. New York: CRC Press.

Photocopier

A photocopier is a machine that makes paper copies of documents and other visual images in an efficient manner and is a tool widely used in the business, education, and government sectors.

In 1881, the earliest version of the photocopier was invented by David Gestetner. It used a Gestetner stencil duplicator, a type of early duplicating machine. It was not until 1938 that the next version of the photocopier was introduced by inventor Chester Carlson. Carlson’s innovations in electrophotography led him to a working copy machine that did not require chemicals or special paper.

In 1959, the photocopier began to use a technological technique known as the xerographic copying process, which works on the basis of electrostatic charges. The xerography process is the dominant method of reproducing images and printing computer data used in photocopiers and also in similar machines, such as laser printers and fax machines. The first xerographic photocopier to hit the market was in 1959, the same year that this copying technique was introduced. In 1968, the Color-in-Color copier appeared, allowing photocopiers to print copies in the same colors as the original. It uses a method known as the dye-sublimation process. The first electrostatic color copier was released by Canon in 1973.

The photocopier has several steps to its functions. To begin, a high-voltage wire known as a “corona wire” gives an electrostatic charge to the surface of the drum, which is coated with a semiconductor material such as selenium or germanium. The light is beamed in thin strips onto the original image, but the light is reflected only by the white areas of the picture. The light then hits the drum, which is specially conditioned to be photoconductive, meaning that the drum neutralizes the positive charges when the light hits it. With the positive charges neutralized, the white areas of the picture become neutral while the black areas are positive. When the negatively charged toner is applied to the drum, it sticks to the positively charged areas. The toner is then attracted to a positively charged piece of paper. The toner is a dry ink substance that is heated to make it melt and to bind it on the piece of paper.

With the technological and digital advancements in scanning and the use of smartphone cameras in the 21st century, it has been predicted that our reliance on photocopiers will decrease. However, higher-end photocopiers are capable of producing color, heavy-duty cycles, and large-format printing, which are in high demand at print and design shops. An array of

photocopier models are available from six major photocopier manufacturers: Brother, Canon, Konica Minolta, Ricoh, Sharp, and Xerox. All copies are often nicknamed “xeroxes,” as Xerox was the first company to mass provide copiers to businesses.

Katarina M. Ponomaroff

See also *Vol. 1, Sec. 3:* Papermaking Machine; Telegraph; *Vol. 3, Sec. 3:* Smartphone and 3G Network

Further Reading

Kuaimoku, Eric. 1994. *Photocopier Maintenance and Repair Made Easy*. New York: TAB Books.

Owen, David. 2005. *Copies in Seconds: How a Lone Inventor and an Unknown Company Created the Biggest Communication Breakthrough since Gutenberg: Chester Carlson and the Birth of the Xerox Machine*. New York: Simon & Schuster.

Pinball and Arcade Games

Arcade games are coin-operated gaming machines typically found in areas frequented by the general public. One of the first of these machines, which popularized arcade games worldwide, was the pinball machine. Over the years, technological advancements have added dimensions of sound, visuals, and score-keeping to enhance the gaming experience, as well as elements of skill required of players. Arcade games gave rise to the current phenomenon of home- and computer-based personal video game consoles.

Originating before the late 1700s, the earliest form of what is now known as pinball was played in France by Louis XIV, where players would shoot balls with a cue from one end and knock down wooden pins on the other. In 1869, a spring launcher was added to the game. This set the foundation for the modern iteration of pinball. The objective of pinball is to score as many points as possible by striking various targets on the pinball play field. The player attempts to score the most points without allowing the ball to fall into the drain and uses “flippers” to help keep the pinball in play. The game ends when all of the pinballs have fallen into the drain.

In the 1930s, the rise of electricity brought major advances to the design of the pinball machine and

added the ability to track the player’s score. In 1947, player-controlled flippers were introduced that allowed the player to attempt to keep the ball in play for longer. Advanced electronic components and digital displays were introduced in the 1970s, which allowed for the introduction of a story element to games. These advancements revolutionized the objectives of pinball, as players now had to hit certain targets to progress the game as it followed the story. Unfortunately, just as these major technological advancements encouraged the gameplay of pinball to new heights, they also brought along new possibilities in arcade games. In the 1980s, the popularity of pinball began to be replaced rapidly by a growing adoration for arcade video games.

Arcade video games boomed in the 1980s, and major games such as *Pac-Man*, *Space Invaders*, and *Galaga* were placed in video arcades across the world, often replacing rows of pinball machines. Arcade video games became so popular that they often showed up in restaurants or bars, and the industry was worth \$8 billion in 1981. Arcade video games added skill elements that stood in contrast with the limited movements allowed in pinball. In games such as *Donkey Kong* and *Space Invaders*, the success of the player was based mostly on the timing of the player’s movements. Culturally speaking, arcade video games sparked a massive interest in video games. In particular, *Pac-Man* generated so much popularity that the buzz surrounding it became known as “Pac-Mania,” and it was even acknowledged by then-U.S. president Ronald Reagan.

Although the rise of arcade video games had been assisted by the arrival of new technological advancements in gaming, it also saw a fall in popularity for the same reason. In the late 1980s, the golden age of arcade video games was coming to an end as new technology brought the invention of personal, home video game consoles. Rather than having to visit their favorite arcade to play video games, it was now possible for people to bring the video games to their homes.

In the 1990s, however, innovations in gameplay allowed for a small “renaissance” of arcade video games. New levels of competition were added so that a player could compete against a friend rather than against the machine. Fighting games such as *Street*

Fighter and *Mortal Kombat* immortalized these new forms of arcade video games. Pinball also enjoyed something of a comeback in the 1990s, as manufacturers had now perfected the use of technology to enhance the pinball gameplay. The two major pinball manufacturers included WMS Industries and Sega Pinball. They contributed to the new interest in pinball by including cultural references in the games. Popular films of the 1990s were licensed to be used in association with pinball machines, such as *The Addams Family*, *Star Trek: The Next Generation*, and an Indiana Jones–themed pinball machine that was aptly named *Indiana Jones: The Pinball Adventure*. However, even though these enhancements generated some interest for pinball in the 1990s, it wasn't enough to measure up to the growth of their video-based counterparts. By the end of the 1990s, WMS Industries had left the pinball industry, and Sega Pinball had sold its division to the sole manufacturer remaining: Stern Pinball.

The 2000s saw interest in arcade video games decline worldwide as personal video game consoles began to dominate the gaming industry. Although the major pinball manufacturers within the United States, such as WMS Industries, had exited the business in the decade prior, smaller, independent manufacturers began to appear and created pinball machines that can still be played today. Arcade video games also evolved from the early days of *Pac-Man* and *Galaga*. Interactive arcade video games in the 2000s included *Dance Dance Revolution* and sit-down vehicle racing games that allow the player to mimic driving a real vehicle. Today's arcade video game industry is small, yet adored. In many countries such as the United States and Japan in particular, arcades have remained popular and remain a major part of the culture.

Alex Vu

See also Vol. 3, Sec. 1: Atari; Baer, Ralph; *Pong*; Vol. 3, Sec. 3: Video Game

Further Reading

Kurtz, Bill. 2004. *The Encyclopedia of Arcade Video Games*. Atglen, PA: Schiffer Books.

Rossignoli, Marco. 2011. *The Complete Pinball Book: Collecting the Game and Its History*. Atglen, PA: Schiffer Books.

Plastic Wrap

Plastic wrap, also known as “cling wrap,” “food wrap,” or “pliofilm,” was originally made from polyvinyl chloride (PVC) or polyvinylidene chloride (PVDC). Eugen Baumen synthesized PVC in 1872 and in 1926, B. F. Goodrich plasticized the compound for use in a variety of applications, including plastic wrap. Dow Chemical discovered PVDC in 1933 and marketed the product as Saran Wrap in 1949. Saran Wrap quickly became popular with Americans and remains widely used in food storage and preservation.

While the vast bulk of plastic wrap is used in food applications, the wrap is sometimes used as a packing material. It is also used in neonatal units, where premature infants are wrapped in the plastic to keep them warm.

Much of modern plastic wrap is still made from petroleum-based plastics, though many companies now make the wrap from more sustainable, vegetable-based bioplastics. Concerns about the interface between PVC and PVDC and food, particularly with the potential toxicity of plastic wrap, has also fueled the bioplastic industry.

Emma E. L. Burke

See also Vol. 2, Sec. 1: Dow Chemical Company; Goodrich, B. F.; Vol. 2, Sec. 2: Bakelite

Further Reading

Freinkel, Susan. 2011. *Plastic: A Toxic Love Story*. Boston: Houghton Mifflin Harcourt.

Radar

Radio detection and ranging, or “radar,” technology depends upon the fact that radio waves reflect off metal. Christian Hülsmeyer, a German, first utilized the phenomenon to detect objects otherwise unseen. In the 1930s, a number of scientists worked to develop radar systems. Scientists working for the U.S. Navy created the first radar tube, which then allowed radar transmitters and antennas to accurately fix long-range targets. Scientists working for the navy developed a ring oscillator that increased radar power, while army personnel

developed more effective antennae for aircraft-based radar. In 1939, the federal government awarded RCA Corporation a contract to mass-produce long-range detection systems. RCA dubbed the technology “RADAR” in 1940. Radar is differentiated from sonar in that radar uses electromagnetic energy in the form of radio waves while sonar uses sound waves and the echo principle.

Hülsmeier first demonstrated a simple ship detection device for the German Navy in 1904. While it was helpful in detecting ships hidden in fog, it could only do so if the ships were nearby. During World War I, English inventors, responding to the rumor that Germany had a “death ray,” developed oscilloscopes to better display signals and better antennae for longer radar range.

Significant headway in radar technology came in the 1930s. In 1934, Robert M. Page, working for the navy, developed a radar device that could detect objects up to a mile away. Page also developed a duplexer that allowed one antenna to be used as both a transmitter and receiver and a ring oscillator that facilitated the use of multiple radar tubes and increased pulse signal. In 1939, the U.S. Navy installed Page’s improved radar system on the USS *California*, a battleship first launched in 1919 and sunk at Pearl Harbor in December 1941 and relaunched in March 1942. The U.S. Army developed and utilized radar technology for World War II bombers like the B-17 and others.

Radar has traditionally been used in military applications, though it was also used in civilian aviation after World War II as well as for weather prediction and mapping applications. Law enforcement personnel use radar guns—really handheld Doppler radar projection apparatuses—to detect the speed of automobiles.

Astronomers also use radar. The Arecibo Observatory in Puerto Rico, owned by the National Science Foundation (NSF), is the largest radio telescope in the world. The telescope collects information for the Search for Extraterrestrial Intelligence (SETI), collects military intelligence, and is used for other scientific research.

Peg A. Lamphier

See also B-17 Flying Fortress; FM Radio; Military Technology (World War II); SONAR; *Vol. 3, Sec. 3*; SETI (Search for Extraterrestrial Intelligence)

Further Reading

- Buderi, Robert. 1998. *The Invention That Changed the World: How a Small Group of Radar Pioneers Won the Second World War and Launched a Technological Revolution*. New York: Touchstone.
- Price, Alfred. 2017. *Instruments of Darkness: The History of Electronic Warfare, 1939–1945*. Annapolis, MD: Naval Institute Press.

Radio. See FM Radio

Refrigerator

Refrigeration is the process of removing heat from an enclosed space, or from a substance, to lower its temperature. A refrigerator uses the evaporation of a liquid to absorb heat. The liquid, or refrigerant, used in a refrigerator evaporates at an extremely low temperature, creating freezing temperatures inside the refrigerator. The year 1859 saw the invention of the first gas absorption refrigeration system using sulfur dioxide, a gaseous ammonia that dissolves in water, and methyl formate as refrigerants. These gases were widely used for that purpose until the late 1920s. These gases were replaced with safer compounds that compress and heat up, working to cool the inside air of the refrigerator.

In the 18th century, people cooled their food with ice and snow, either found locally or brought down from mountains. For centuries, people used large blocks of ice to keep food cold, and some only chilled food seasonally, taking advantage of cold ambient temperatures. In 1834, Oliver Evans, an American inventor, designed the first refrigeration machine. The first practical refrigerating machine was built by Jacob Perkins, the “Father of the Refrigerator.” In 1876, Carl von Linden, a German scientist, invented and patented the process of liquefying gas that is part of basic refrigeration technology. Ammonia, sulfur dioxide, and methyl formate compound were utilized as refrigerants. Fred W. Wolf invented the first refrigerators for kitchen appliance and domestic use in 1913.

Due to several fatal accidents that occurred due to the use of these gas compounds; three American corporations developed a less dangerous method of

refrigeration. Their efforts led to the discovery of Freon, but it, too, became a problem. Its chlorofluorocarbons deplete the ozone layer and have high global warming potential.

In the United States, the refrigerator became an essential piece of kitchen furniture. In the 1950s, over a million of them were manufactured. Mass production of modern refrigerators began in earnest after World War II. More than 80 percent of American farms and more than 90 percent of urban homes had one. New refrigerants were developed in the early 21st century that are safer for the environment, but their application has been held up due to concerns over toxicity and flammability.

Rosanne Welch

See also Freeze-Dried Food; *Vol. 2, Sec. 1: Food Preservation*

Further Reading

“Engineering and Technology History.” <http://ethw.org/Refrigerator>, accessed August 29, 2018.

Grahn, Emma. “Keeping Your (Food) Cool: From Ice Harvesting to Electric Refrigeration.” *The National Museum of American History* (blog). <http://americanhistory.si.edu/blog/ice-harvesting-electric-refrigeration>, accessed August 29, 2018.

The Inventors. <http://theinventors.org/library/inventors/blrefrigerator.htm>, accessed August 29, 2018.

Richter Scale

The earthquake magnitude scale, the Richter scale, named after its creator Charles Richter, is a numerical scale used on the recordings of seismographs. The scale measures the amount of energy that earthquakes release and establishes a numerical rating for that earthquake that describes its size. The more energy released, the higher the earthquake’s number on the scale.

In the 1930s, California Institute of Technology professor Charles F. Richter decided to create a system that would accurately measure seismic activity. He did some earthquake measuring tests in early 1932. In 1920, Richter had read Japanese seismologist Kiyoo Wadati’s paper on earthquake depths. Wadati, who worked at the Central Meteorological Observatory in

Japan, studied earthquakes and determined the connection between surface displacement and distance from quake epicenters.

Richter began to gather data from previous earthquakes in Japan and by measuring current quakes. He began plotting data on a numerical scale and further systematized it. His magnitude scale resembles the stellar magnitude scale used in astronomy to measure the brightness of an astronomical object as seen by an observer on earth. It wasn’t until 1978 that this magnitude scale used to rank earthquake was referred to as the Richter scale.

Richter based his measuring system on logarithmic equations that could tell what the size of an earthquake was. In the 1930s, there was no reliable system in place that could interpret seismic activity data as a quantitative scale. In its early stages, the Richter scale was unable to measure smaller earthquakes or aftershocks because seismic instrumentation was not yet sensitive enough. It also could not characterize earthquakes of similar measurements as different types. Seismologists later discovered that earthquakes vary in the direction of vibration, so despite them having the same numerical readings, the destruction caused by high-level earthquakes is not the same. With further development, the Richter scale became the standard for measuring earthquakes.

Adolfo Alarcon

See also *Vol. 3, Sec. 1: Hydraulic Fracturing (“Fracking”)*

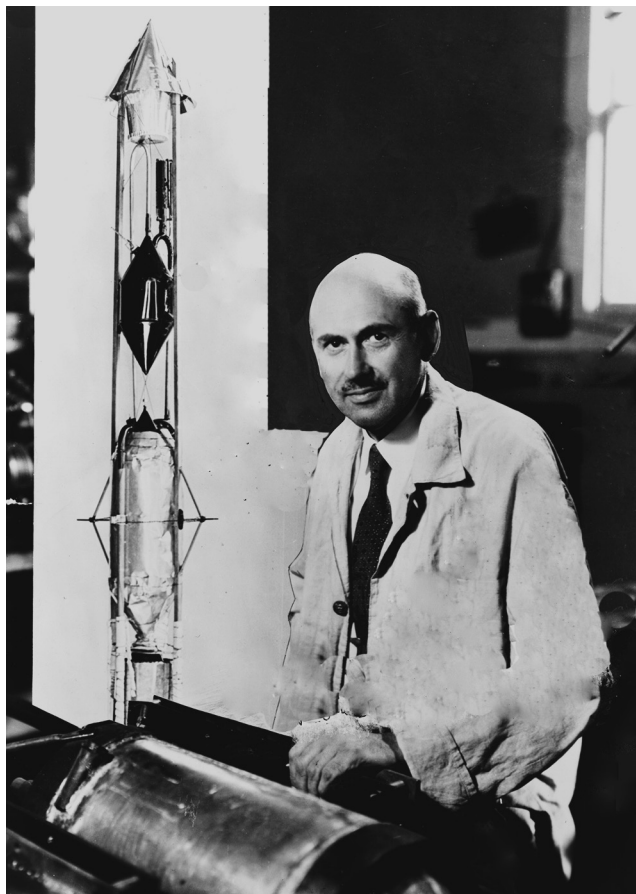
Further Reading

Miles, Kathryn. 2017. *Quakeland: On the Road to America’s Next Devastating Earthquake*. Boston: Dutton.

Richter, Charles. “Interview by Ann Scheid. Pasadena, California, February 15–September 1, 1978.” *Oral History Project*, California Institute of Technology Archives.

Rocketry (Pre–Space Age)

Any vehicle, from missiles to aircraft, that propels itself with a rocket engine is considered a rocket. Rocket engines create thrust with propellant self-contained in



Robert H. Goddard is the father of American rocketry. His theories on spaceflight, while considered ridiculous in the early 20th century, have now been proven accurate. (Library of Congress)

the engine, which, when expelled, causes forward movement in the opposite direction of the exhaust. Robert H. Goddard created the world's first liquid-fueled rocket in 1926. The science of rocketry has had to overcome several problems, including engine and thrust mechanics, the effect of gravity (both earth and celestial) on rockets, the drag that rockets create and, for rocket-powered aircraft, problems of lift.

For most of world history, space exploration and travel only existed in fiction. For example, Jules Verne's (1828–1905) *De la terre à la lune* (*From Earth to the Moon*) and *Autour de la lune* (*Around the Moon*) from the 1850s explored the theory of space travel. His novels brought the idea to the masses. Based on theoretical scientific work, Verne wrote vivid descriptions of the moon and details of how outer space was vastly different from Earth.

The father of cosmonautics, Konstantin Tsiolkovsky (1857–1935), credited Jules Verne's novel *From Earth to the Moon* for his curiosity about the distance of traveling to the moon. Tsiolkovsky researched ideas for steering thrusters, space stations, and airlocks for exiting a spaceship into the vacuum of space, as well as closed-cycle biological systems to provide food and oxygen for space colonies. Tsiolkovsky's contributions to rocketry were formally recognized in 1921.

Scientists working in early 20th-century rocketry research were mainly concerned with exploring new ways to construct weapons of war, much like those who worked on advancements in airplanes and submarines during World War I and World War II. After the Wright brothers successfully flew an airplane in 1903, interest in rocketry increased. Mathematicians focused on calculating velocity and trajectory, while many other researchers began studying propulsion systems.

Robert Goddard, an American scientist, successfully launched the world's first liquid-fueled rocket in March 1926. In 1919, Goddard published *A Method of Reaching Extreme Altitudes*, a report that explained his theories of rocket-propelled flight. In the report, Goddard mentioned the possibility of reaching the moon with a rocket. This theory caused an uproar among the scientific community and the public. While many people ridiculed the notion of moon travel, others found the idea exciting and plausible. Though controversial at its publication, the report is now viewed as one of the germinal works of rocketry science.

Goddard's first rocket traveled only meters in height, but he and his team continued to work on the technology. By 1941, Goddard had launched 34 rockets, the most successful of which traveled 1.6 miles. Goddard's 214 patents make him one of the great rocketry scientists and the father of modern rocketry and the space age. Nonetheless, the U.S. government was unenthusiastic about funding rocketry research. This left the next generation of rocketry advances in the hands of European scientists.

Germany would conduct an immense amount of research into the deployment of rocket missiles to ensure that they would not violate a treaty after World War I. Long-range artillery was the key solution for new weapons; the A2 rocket was created, and its successors were developed into the very first missiles, which would be

used in World War II. With further research and development, the V-2 was the world's first military ballistic missile and was the prime foundation for many rockets that borrowed its design around the world. During the last months of World War II, many German scientists were captured by or surrendered to the United States and the Soviet Union, bringing along their extensive knowledge of rocketry. The arms race would be fierce, as now both of these world powers gained rocketry knowledge that used to be in the hands of German scientists and engineers. The achievements led to many of the world's first space experiments. October 4, 1957, is regarded as the first day of the Space Age. It was the day that Sputnik, a Russian satellite, was first launched, and the world catapulted into a fascination with space travel.

The United States made a significant commitment to fund rocket-powered space flight. In 1961, President John F. Kennedy announced that NASA would land a manned rocket on the moon by the end of the decade. The birth of the Apollo program allowed for huge strides in rocketry science that culminated in the 1969 moon landing. NASA's reusable, low-earth orbital program, known as the Space Shuttle program, combined rocketry with aircraft technology. Shuttles used solid rocket boosters to make 135 missions between 1981 and 2011.

In the late 20th century, hobbyists took up rocketry as model rockets became commercially available. Water, hydrogen peroxide, and other materials fuel hobby rockets, which come in three categories: low power, mid power, and high power.

Adolfo Alarcon

See also *Vol. 2, Sec. 1:* Wright, Wilbur and Orville; *Vol. 3, Sec. 1:* Apollo Project; Mercury 13; National Aeronautics and Space Administration (NASA); *Vol. 3, Sec. 2:* Space Shuttle; *Vol. 3, Sec. 3:* Cassini Saturn Mission; Mars Rover Series

Further Reading

Macdonald, Malcolm. 2014. *The International Handbook of Space Technology*. London: Springer Praxis Books.

Winter, Frank H. 1983. *Prelude to the Space Age—The Rocket Societies: 1924–1940*. Washington, D.C.: National Air and Space Museum, Smithsonian.

Rosie the Riveter

The “Rosie the Riveter” icon began as a propaganda symbol that encouraged a collective effort from all American women during World War II (1939–1945). In another sense, Rosie was a symbol of the wartime sacrifices and discrimination that women endured during the war. In later years, feminists redefined the Rosie the Riveter image as a symbol of female empowerment. Though this iconic poster is but one of many images that encouraged women in World War II to take on war work, it is the most famous. The “Rosie the Riveter” campaign encouraged American women to think of their waged labor as positive and patriotic. During the war, there was a shortage of labor in the factories, because millions of men had gone off to fight. To keep the country running and to provide the troops with needed materials, the federal War Manpower Commission and the Office of War Information (OWI) began a large propaganda effort known as the “Women in War Jobs” campaign. The campaign first targeted women already in the workforce by encouraging them to seek higher-paying wages in factories. Then, the campaign recruited young girls out of high school. Finally, when officials realized that even more workers were needed, they targeted older married women who had children and had not previously been expected to work outside the home.

Many ads appealed to patriotism. One ad advised, “Do your part, free a man for service.” Other ads told women that if they joined the workforce, the war would be over sooner. Some ads attempted to generate fear and guilt by telling women that more soldiers would die without their help. Furthermore, many propaganda posters underscored the specific dire need for industrial workers, and industrial leaders advertised high wages. Not surprisingly, about half of all women in the workforce during the war were employed in defense-related industries. About 6 million women answered the call. Some worked under very dangerous conditions in munitions factories. Many did heavy factory work that had been previously reserved for men: building aircraft and warships. Women drove streetcars, operated heavy construction machinery, and unloaded freight. Women were toolmakers, machinists, lumberjacks, blacksmiths,

steel mill workers, railroad workers, and riveters who built war machines.

Artists celebrated Rosie the Riveter in popular songs and paintings. Norman Rockwell painted a female riveter for the cover of the Memorial Day edition of the *Saturday Evening Post*, using a dental hygienist named Mary Doyle Keefe for his model. Rockwell's figure's pose resembled the pose of the prophet Isaiah in Michelangelo's Sistine Chapel ceiling painting. In a patriotic vein, an American flag waved behind a redheaded Rosie wearing a blue uniform with white pins on her chest. Evidence of the riveter's work ethic could be seen in the residue on her face and arms. As if to show that women's industrial work could help defeat Adolf Hitler, a riveting gun lay on the worker's lap while a copy of *Mein Kampf* lay under one of her feet.

After Rockwell's portrait was published, the press found and celebrated several real women they could associate with the powerful image, the most famous of these being Rose Will Monroe, who worked as a riveter on B-24 and B-29 bomber airplanes in Ypsilanti, Michigan.

After the war, the image of Rosie the Riveter was almost forgotten. It was not until a wave of feminism swept the nation in the 1980s that the concept of Rosie the Riveter was resurrected. However, due to copyright restrictions on Rockwell's work, feminists adopted a woman's image from an earlier painting. In 1942, the Westinghouse Power Company had commissioned J. Howard Miller to design a propaganda poster to use to increase the morale of its workers. Miller created a poster of a woman wearing a bandanna and flexing her arm muscle with a caption reading, "We Can Do It." Since the 1980s, the Miller poster has become one of the most recognized symbols of female empowerment. In this way, the Rosie the Riveter image went from being used as a wartime recruitment propaganda tool to a symbol of past injustices and a rallying call for women's empowerment.

Women who took jobs in industrial work often faced negative attitudes from male coworkers. In extreme cases, factory managers refused to provide women with gender-separate restrooms. Although women usually earned more doing factory work than

any other work, they were sometimes paid 50 percent less than their male factory coworkers. In addition, women were often denied access to certain hazardous but higher-paying occupations, such as sandblasting. Promotions in pay and rank were often given only to men. African American women, usually employed as factory janitors and sweepers, remained even lower on the job ladder than white women.

After the war, both commercial and military sectors wanted women to leave the factories so that returning men could have their jobs. Consequently, the government launched a new propaganda campaign asking women to "return to normalcy." The message was that it was not "normal" for women to work in factories. The crisis of war was over, and the aid that women had provided was no longer needed. In short, Rosie the Riveter was laid off in 1945.

Working in the factories had demonstrated to women and to the world that they could do jobs that had been previously thought exclusively suited to men. In fact, although many women were let go from their factory jobs in 1945, an increase in postwar spending brought many women back to the factories a few years later. Even by 1947, the percentage of women in the workforce had risen to the same level it had been in 1940. In the long run, women's work experiences during the war served as a precursor to the more permanent employment opportunities that women enjoyed in the 1970s and 1980s. Today, Rosie the Riveter is a symbol of not only what was but also of what can be.

Rolando Avila

See also Curtiss-Wright Aeronautical Engineering Cadettes; Women's Airforce Service Pilots (WASPs)

Further Reading

- Gluck, Sherna Berger. 1987. *Rosie the Riveter Revisited: Women, the War, and Social Change*. Boston: Twayne.
- Honey, Maureen. 1984. *Creating Rosie the Riveter: Class, Gender, and Propaganda during World War II*. Amherst: University of Massachusetts Press.
- Wise, Nancy Baker, and Christy Wise. 1994. *A Mouthful of Rivets: Women at Work in World War II*. San Francisco: Jossey-Bass.

Primary Document: Excerpt from Interview with Maria Isabel Solis (2003)

Americans scrambled to fill all the wartime jobs created by the United States' entry into World War II. Women of all types and classes worked in wartime factories, doing the kind of heavy industrial manufacturing previously thought only the province of men. Maria Isabel Solis Thomas worked in a shipyard with women from all over the country. Her experience was both empowering and life changing, in part because she learned that she and other women could do what people said they could not do.

Maria Isabel Solis Thomas: When we went to work in California, my sister and I, we, oh my god . . . there were girls there, oh my god, from all over . . . They were Italians or they were Portuguese or whatever, but then there were a lot of Mexican girls, real nice girls. They, like I say, they were from Denver, Colorado, they came from Seattle, Washington, they were, well, they was far from Pennsylvania, there was some girls that came from over there 'cause their families had moved there and I went to work in a shipyard we met all these girls from all over and we were staying in these, ah, we ourselves in these girls dormitories. When we went over there, realize real neat, everything was so beautiful we thought oh, it looked like when you're in school, in girls' dormitories, you go someplace else you know all the girls and it was so beautiful, everybody friendly and conversing with one another and all of that, but I'll assure you one thing that I would say that about at least 40% of the people that were there they were Mexicans—Mexican girls. We got up at three o'clock in the morning, got ready by five, took off at five, 'cause we have to be at work by six but we stop on our way at a little restaurant and had breakfast, and took our lunch, and whatever, and went to work.

Interviewer: So what kinds of things were you doing at work?

2

Maria Isabel Solis Thomas: Oh well we had to . . . it was dangerous . . . and it was dangerous and, ah, we, ah wherever there was needed . . . see . . . it concerns us . . . was pipes . . . nothing else . . . plate was somebody else who had to weld the plates and

different things. We, it was the pipes, the pipes on the railings, pipes that were the water pipes, this pipe, whatever pipe, and the most, how can I say, delicate and stuff it was a tiny, tiny little pipe that came in the front of the ship and it was a little stand like this, a platform on the top you know with the holes on it or whatever . . . it stood on a base no higher than . . . and oh my god. And then they wanted me to get under there, in the center, there was a little pipe coming out, that, well, was the radar. And it's very delicate. And you have to know precise, exactly precise how to strike the rod and at the same time how to weld around, clear around it and seal it, see, 'cause it had to be sealed. And not to make a hole, not to do damage to it.

And oh my goodness . . . and we were really, we were very thin, we were very small, just kids, like I say kids, but we were very thin. We were always playing . . . making exercise and what . . . I think that's why, and we walked a lot, and so we were very thin, short and thin, but then we have to wear all this uniform—this stuff—we wore coveralls, and then we worked, on top we wore. I wish we could have been able to take pictures of ourselves over there . . . we were not allowed—not in the shipyard or any place around there—nobody could take pictures. There was a war going on, you ain't gonna be taking pictures of no shipyards or anything but anyway . . .

Interviewer: But World War II had already started?

Maria Isabel Solis Thomas: It was under full force. There was in [19]44 there was in full force, and that's why they needed us to go and help 'em build these ships, to get 'em out, 'cause they needed the ammunition, they needed the food, and [to] transport these boys where they had to go, okay?

And so, like I say at that time, to crawl under there, and with all of this mess that you had, so I had to take just about everything, all these things off, and just a hood, in my glasses they give you, so that you won't burn your eyes and get under there, crawl under there, and seal it. I was so proud, 'cause man, I did it just exactly the way they wanted to, and here I come up and [they say] "Hi Shorty, you did pretty good!" [Laughs] But anyway, at the same time, it was fun for

us you know, crazy kids, but at the same time we were very proud that we were doing something good, something to help, to help the boys really, we never thought about being patriotic or being . . . because we were doing it for our country though we believed that we were helping these boys, these young men that were out there and were going out over there. 'Cause and we see 'em when they were shipped out and oh, their sad faces and everything, it was very hard. And so I don't know, it's . . . I can't explain, but it's very hard. It's very hard. And so if we're going over ____ [?] ____ , I was wearing little bitty earrings that had a tiny little bitty cross, and he looked right at me so funny, and he says "Can you give me one of your earrings?" I looked at my earrings and said, "Oh boy," and my sister looked at me and I look at—we're standing there like fools you know—but I had the turban, and at the same time I guess it come out and you could see it I was always wearing earrings, my goodness, for my sister always used to say "She's got no shoes on, but she's gotta wear earrings." So anyway, and so I felt sorry for him, and I took it off and gave it to him, and then the other boy, it was the other sailor that was there, you see they were crossing they were going into their ship, he says "How 'bout the other one?" I said OK so I took it out and I gave it to the other boy. We never seen them again, I don't know who they were or whatever, but anyway it was sad . . . it was sad. Anything, any little thing, it means something to them.

Maybe to remember the girls who were there or whatever, but uh . . .

Interviewer: Did you have a lot of contact with the soldiers?

Maria Isabel Solis Thomas: No. No, no, no, no this is when they were boarding their ship. See, they brought in their ships when they were damaged . . . in there and we got to see 'em. It was very sad. But then . . . but then . . . no, no, our job was to do the work, to do the work there wherever we were needed, whether at the top of the deck, whether it was to the bottom or on to the boiler room, everywhere we were needed we went. This was, it was dangerous, it was because there were some places that were very, very dangerous, even for a man, and yet we kids went and did the job without even, without a second thought. That's what they needed, we were gonna do it. And thanks be to God everything was fine. We were both fine, and in fact and like I say on some of these . . . that's when we had the rest, then we would go and visit or go into San Francisco, we just a few miles from there. Pick up the bus and go with a whole bunch of girls . . . Lina, Rosa, Virginia, this that girls from all over the country, I tell you it was like this . . . all women!

Source: Courtesy of the VOCES Oral History Project, Nettie Lee Benson Latin American Collection, University of Texas at Austin.

Schwinger, Julian (1918–1994)

Schwinger was a revolutionary American scientist known for his contributions to the quantum theory of electrodynamics. His work won him a Nobel Prize in Physics in 1965. Schwinger became an early scholar in physics, publishing his first work at age 16. He received his PhD in 1939 from Columbia University. Schwinger quickly moved on to work at the University of California, Berkeley.

In his first year at Berkeley, Schwinger became a National Research Fellow in physics, and the following year he became an assistant to Julius Robert

Oppenheimer, the well accepted "father" of the atomic bomb. In 1941, Schwinger became an instructor at Purdue University, and by 1942, he had become an assistant professor.

Life took a more serious turn for Schwinger in 1943, when he was enlisted for the technological battle in World War II. Schwinger originally had been given leave from Purdue to assist at the Radiation Laboratory at the Massachusetts Institute of Technology. This led to Schwinger being asked to help with the development of the atom bomb in Chicago. Schwinger's distaste for the bomb caused him to move to Boston, where he worked with a former teacher of his,

Dr. George Eugene Uhlenbeck, on radar. Schwinger was a dedicated night worker and was cited by Uhlenbeck as being mathematically adept. During his time of leave at Purdue, Schwinger was granted the title of research professor in theoretical physics. Despite this, when Schwinger's assistance with war efforts ended as the war did, he opted to resign from Purdue in favor of a position at Harvard, where he would work for 27 years (1945–1972). He began as an associate professor in 1945 but quickly was promoted to a full professor in 1947. Also that year, Schwinger married Clarice Carroll.

At this point in his life, Schwinger began to turn to theoretical work more than practical. In 1951, he coined the phrase “Schwinger effect,” an idea in thermodynamics that has not been confirmed by an experiment yet; he also was granted the first Einstein Prize that year.

Schwinger's big breakthrough came in 1957, when his work led him to the discovery and invention of source theory, which is largely responsible for the basic scientific understanding of nearly everything physical. This work is predominantly why he became the joint winner of the Nobel Prize in 1965 with Richard Phillips Feynman, who had researched the findings that Schwinger discovered. Schwinger's discovery is notable for putting quantum mechanics in alignment with Einstein's theory of relativity.

Schwinger's life transitioned to focus more on the development of new scientists in his later years. Schwinger moved from teaching at Harvard to the University of California, Los Angeles, in 1972, where he stayed until his death in 1994. Schwinger's nearly 60 years of contributions to physics in the 20th century, as well as his capability as a teacher, have made him one of the most impactful characters on science in the modern era.

Cassady O'Reilly-Hahn

See also Atomic Bombs/Nuclear Weapons; Manhattan Project; Oppenheimer, J. Robert; Radar; *Vol. 2, Sec. 2*: Einstein, Albert

Further Reading

Martin, Paul, and Sheldon Glashow. 1995. “Julian Schwinger: Prodigy, Problem Solver, Pioneering Physicist.” *Physics Today* 48, no. 10: 40–46.

Milton, Kimball. 2007. “In Appreciation Julian Schwinger: From Nuclear Physics and Quantum Electrodynamics to Source Theory and Beyond.” *Physics in Perspective* 9, no. 1: 70–114.

Saxon, David S. 1994. “Julian Schwinger.” *Nature* 370, no. 6491: 600.

Semple, Ellen Churchill (1863–1932)

Ellen Churchill Semple was an American geographer, author, and educator. She was one of the first female professional geographers in the United States and was the first woman to serve as president of the Association of American Geographers. Her theory of environmental determinism, although controversial by the mid-20th century, shaped the field of human geography.

Semple was born on January 8, 1863, in Louisville, Kentucky, to Alexander Bonner Semple, a successful businessman, and Emerine Price. The youngest of five children, all daughters, she followed her older sister, Patty, to Vassar, graduating with a BA in 1882. Upon her return to Louisville, she turned her scientific interests to her Kentucky surroundings, studying local populations and constructing her theoretical framework of environmental determinism—the idea that the natural environment controls a population's history and culture. In 1891, she earned an MA from Vassar for her thesis, “Slavery: A Study in Sociology.”

While visiting London in 1887, Semple met Duren John Henderson Ward, who introduced her to the work of his professor, Friedrich Ratzel. Ratzel founded a discipline called anthropogeography, now referred to as “human geography,” at the University of Leipzig. Semple studied with Ratzel between 1891 and 1893. Although women could not matriculate at Leipzig, Semple obtained permission to attend Ratzel's lectures, as well as seminars in economics and geography. With his encouragement, she began publishing her geography writing. In 1901, she published *The Anglo-Saxons of the Kentucky Mountains*, a detailed, fieldwork-based study of the eastern part of the state and its people before it was altered by coal mining.

In 1903, she published *American History and Its Geographic Conditions*, which brought her national

attention. She became a charter member of the Association of American Geographers in 1904, one of only two women invited to do so. In 1906, she was appointed lecturer in geography at the University of Chicago, and as an educator, she emphasized the importance of fieldwork and original research. Her next book, *Influences of Geographic Environment*, appeared in 1911 and introduced Ratzel's theories of anthropogeography to American audiences. She attempted to demonstrate how various elements of the natural environment affected human culture, social development, and migration.

In 1921, Semple was elected president of the American Association of Geographers and received her first full-time academic appointment as a professor of anthropogeography at Clark University. She was the first female faculty member at Clark, though the university paid her significantly less per year than male faculty members, arguing that she was a woman without dependents. Her final book, *The Geography of the Mediterranean Region: Its Relation to Ancient History*, was published in 1931. It described how the landscape of the Mediterranean basin gave birth to Western civilization. By this time, however, the theory of environmental determinism had fallen out of favor with mainstream geographers, and the book was largely ignored. Semple died on May 8, 1932, in West Palm Beach, Florida.

Kathleen Barker

See also Calutron Girls; Lange, Dorothea; Mead, Margaret

Further Reading

Keighren, Innis. 2011. *Bringing Geography to Book: Ellen Semple and the Reception of Geographical Knowledge*. London: I. B. Taurus.

SONAR

Sonar, also known as SONAR, an acronym for “sound navigation and ranging,” a term first coined by the U.S. Navy during World War II, is a method of harnessing sound energy to communicate and sense objects primarily through the medium of water. Sound



Increased interest in detecting submarines during World War I led to the development of sonar. Sonar machines, like the PC-488, could send out sound pulses and measure their return when reflected off a hard surface. (Corbis via Getty Images)

waves have a distinct advantage in transmitting information underwater due to their higher range of penetration as compared to electromagnetic waves. It is for this reason that sonar eventually became instrumental for antisubmarine warfare in naval forces.

Sonar systems generally fall into one of two groups: passive systems or active systems. In passive systems, objects to be detected are the primary source of signal generation; signals are detected by the observer through a receiver. On the other hand, active systems, also known as echo-ranging systems, generate a signal through a transmitter, which then radiates toward an object and is reradiated back to the receiver.

Although previous efforts to exploit the propagation of sound waves underwater have been recorded as far back as 1490 by Leonardo da Vinci, it was not until 1906 that American shipbuilder Lewis Nixon, inspired by the need to detect submerged icebergs at sea,

created the first sonar device. However, in 1912, the RMS *Titanic* struck an iceberg in the North Atlantic Ocean, which caused it to sink. This incident was one of two significant events that acted as a catalyst for increased attention to the development of sonar technology. Soon after, in 1913, a patent was awarded to Canadian American Reginald A. Fessenden for his underwater transducer, which was capable of detecting an iceberg 3.2 kilometers away.

As sonar continued to evolve, so did political tensions throughout Europe. By 1914, the world had entered the First World War. Submarines became a premier threat in naval warfare because of their ability to go undetected by traditional observational systems. Both the British and U.S. militaries aggressively sought to exploit echo-ranging technology as a solution to this new military dynamic. By 1919, ships equipped with Allied Submarine Detection Investigation Committee (ASDIC) systems were capable of detecting objects while in motion.

Over the next several years, the U.S. Navy reduced its sonar frequency from 20–50 kHz to 15–20 kHz, thus increasing its range. During the Second World War, sonar had become a powerful tool for locating enemy ships, and nearly all U.S. destroyers had echo-ranging technology. This proved to be effective and played a paramount role in controlling ocean territory.

Apart from military operations, sonar has been used in many other applications including fisheries, ocean floor mapping, unmanned underwater vehicles, and submerged airplane retrieval systems. Echolocation, the biological equivalent of active sonar technology, is used as a form of communication by animals such as bats, dolphins, and even some humans who suffer from blindness.

Jonathan G. Herrera

See also Military Technology (World War II); Submarine Technology; *Vol. 2, Sec. 1: Military Technology (Post–Civil War through World War I)*

Further Reading

D’Amico, Angela, and Richard Pittenger. 2009. “A Brief History of Active Sonar.” *Aquatic Mammals* 35, no. 4: 426–34.

Horton, Joseph Warren. 1959. *Fundamentals of Sonar*. Annapolis, MD: United States Naval Institute.

United States Navy Department, Bureau of Ships. 1965. *Introduction to Sonar Technology*. Washington, D.C.: Bureau of Ships, Navy Department.

Submarine Technology

A submarine is a type of watercraft that can operate underwater. Submarines were developed in the early 18th century and have considerably changed over the years. The key importance of the submarine was its strategic advantage for military use. Submarines were key in performing naval tasks such as protecting aircraft carriers, reconnaissance missions, and other tasks.

Submarine technology advanced significantly during World War II and the late 20th century. Pre–World War II submarines peaked in prominence through advances made by German engineering. Called U-boats, German submarines were known for their ability to withstand high water pressure as well as to adjust for buoyancy when diving below the water’s surface. Its structure was that of a cylindrical boat with two hulls: an inner hull and outer hull. The purpose of the inner hull, also called the “pressure hull,” was to protect the crew working inside from the intense water pressure and freezing temperatures of the deep sea. The outer hull took the shape of a cylinder. The U-boat had tanks throughout that controlled its buoyancy. It also included internal combustion engines and a periscope. These 200-ton U-boats were also equipped with torpedoes, deck guns, and mines. The German U-boat was the most formidable naval weapon of World War I.

Submarine technology continued to accelerate during World War II. The Allies and Axis each had about 2,000 vessels serving in the war. German U-boats were known in World War II for their ability to block the supply routes of the Allies, though both sides wreaked havoc on the other during the war. Winston Churchill commented once that German submarines had had such a significant damaging effect that they almost led to British surrender. The Vetchin-class U-boat had an improved engine and greater fuel capacity. These submarines were about 500 tons

and had diesel-electric engines. They were armed with six torpedoes and 20 mines each, and had other improvements.

During World War II, most U.S. naval submarines were 300-foot, 1,450-ton crafts armed with dual-purpose guns, automatic weapons, and torpedoes. Navigation advances in the periscope provided the observer in the submarine with a view of the surface of the sea. In this war, there were improved torpedoes as well as improvements to radar. Early radar models gave insight to when an aircraft appeared nearby, but during World War II, radar could sweep the surrounding sea for targets. Its plan position indicator displayed an image on a screen, providing a clear indication of targets' positions. Improvements in submarine technology allowed the United States to sink about 5 million tons of Japanese merchant shipping during the war. Submarines also sank over 550 Japanese ships.

Toward the end of World War II, snorkels were added to submarines. The snorkel allowed fresh air into the vessel for breathing and to ventilate engine exhaust fumes. This enabled the submarine to stay below surface with its engine running while recharging its batteries.

After World War II, in 1954, the United States issued the world's first nuclear-powered submarine, the USS *Nautilus*. Nuclear submarines were quiet and heavily armed. They could stay underwater until their food supplies were exhausted. The *Nautilus* outperformed all other submarines at the time because of its overwhelming effectiveness and power, in great part because it ran on controlled nuclear fission that converted water into steam for its turbines. The engine had two systems of pressurized water sent throughout the engine. One system circulated water throughout the reactor and eventually reached the steam generators. The water reached the secondary system of water, where it was heated into steam. The steam entered the turbines to generate power for the submarine and was then condensed in tubing, reverting it into water. This system allowed the submarine to be submerged for long periods and to move at immense speed. In 1958, the *Nautilus* crossed beneath the Arctic ice cap and was also able to circumnavigate the world in 1960.

Nuclear weapons were implemented into the submarines, as well as changes to their shape. Structural

changes gave them a teardrop shape, allowing vessels to dive into the water at a top speed of about 40 to 45 miles per hour. During the Cold War, the U.S. Navy continued to develop different types of nuclear-powered submarines. The first type was the strategic deterrence patrols (SSBNs) equipped with nuclear missiles. The continually moving position of the SSBNs made them difficult to track.

Hunting submarines were equipped as seek-and-destroy enemy patrols. Special operations submarines were deployed on special occasions to fulfill particular national agendas. Each of these nuclear submarines was equipped with different missiles. A Tomahawk cruise missile could strike at faraway target with accuracy, while the Polaris ballistic nuclear-armed missile launched from a concealed location but with low accuracy. The Poseidon missile later replaced the Polaris; it was more accurate and had greater range.

Advancements in submarine technology continue. In the 21st century, although major submarine combat has dropped significantly, submarines still have the ability and power to drastically affect the future in many ways.

Jacky Voong

See also Radar; SONAR; *Vol. 1, Sec. 1: Turtle Submarine*; *Vol. 1, Sec. 3: Torpedo*; *Vol. 2, Sec. 2: Turbine Engine, Gas Powered*; *Vol. 3, Sec. 2: Nuclear Energy/Nuclear Power Plants*

Further Reading

- Moore, J. E. 1976. *Jane's Pocket Book of Submarine Development*. New York: Macmillan.
- Reed, W. Craig. 2010. *Red November: Inside the Secret U.S.-Soviet Submarine War*. New York: William Morrow.
- Sontag, Sherry, and Christopher Drew. 1990. *Blind Man's Bluff: The Untold Story of American Submarine Espionage*. New York: Harper Paperbacks.

Tampon

A tampon is composed of material, usually cotton, that absorbs menstrual fluid when placed inside the vagina.

The idea of tampons is not new. Ancient Egyptians made tampons from softened papyrus, while

ancient Greeks used lint. The modern menstrual tampon, which consists of a plug, applicator, and string, was invented in 1929 by American osteopathic physician Earle C. Haas (1888–1981). In 1931, Haas applied for a patent for his invention, and in 1933, he sold his patent and trademarked brand name “Tampax” (which he created by combining the words “tampon” and “vaginal pack”) to Gertrude Tenderich for \$32,000. Tenderich, an immigrant from Germany, started the Tampax Company in 1936. She made the first Tampax tampons using her own sewing machine.

Although the tampon has since had a major impact on how women treat their menstrual flows, the public initially resisted menstrual tampons. Women also questioned the hygiene of the tampon and worried about its impact on female virginity. Many were afraid that the device might lead to irritation, menstrual blockage, infection, and even sterility. In the 1940s, advertisements in the *Journal of the American Medical Association*, national newspapers, and popular ladies’ magazines used patriotism to attract would-be users by proclaiming that tampons freed up raw materials that could be used in the World War II effort. Tampax reinforced these cultural messages by sending “demonstrators” to local department stores to sell their product in person. By the end of the decade, one out of every four American women used tampons.

In the post–World War II years, as American women became more active in the workplace and in organized athletics, tampons gained increasing market acceptance. By highlighting the idea that tampons were more discreet than pads (they are less bulky and do not show under clothing), advertisers convinced a whole generation of women to replace their “old-fashioned” sanitary napkins. Today, tampons are most popular among American women; around 70 percent of menstruating women in the United States use them. According to Karen Houppert, as of 1999, only 3 percent of Asian and Latin American women used tampons, which may be linked to the importance placed on physical (that is, hymeneal) virginity in these regions of the world.

In the late 1970s and early 1980s, researchers found that some tampons caused toxic shock syndrome (TSS). Though incidents of TSS were rare, the public reaction against tampons in general was

considerable. In the 20th century, tampons have come to represent unhealthy and environmentally unfriendly products for many women. Critics suggest that bleached, mass-produced cotton exposes a woman’s body to carcinogens and other potentially deadly substances. Moreover, cotton is an environmentally unsustainable agricultural product requiring massive amounts of water, pesticides, and chemical fertilizers. Tampon alternatives include more environmentally friendly products such as organic sanitary pads and reusable or disposable menstrual cups (the most popular brands are the Keeper, Moon Cup, and Diva Cup), which resemble diaphragms but are intended to trap menstrual fluid.

Peg A. Lamphier

See also Vol. 2, Sec. 1: Vibrator; Vol. 3, Sec. 1: Birth Control Pill

Further Reading

Houppert, Karen. 2000. *The Curse: Confronting the Last Unmentionable Taboo: Menstruation*. New York: Farrar, Straus & Giroux.

Kissling, Elizabeth. 2006. *Capitalizing on the Curse: The Business of Menstruation*. Boulder, CO: Lynne Rienner.

Tea Bag

Tea bags, defined as small, porous bags filled with tea leaves or powder and immersed in hot water to make individual portions of tea, are a relatively modern invention. For thousands of years, the brewing of tea required precise measurement and steeping times, in addition to careful removal of the leaves before consuming the beverage. The invention of the tea bag streamlined the process and reduced waste by allowing individuals to brew tea by the cup. Thomas Sullivan, a tea merchant from New York, is generally credited for accidentally inventing the tea bag in 1908. However, the modern tea bag was actually invented at least seven years earlier; Roberta Lawson and Mary Molaren filed a patent for a “tea leaf holder” in 1901.

The practice of boiling plant leaves to make a tea originated in China between 3000 and 1600 BC. Tea

was prepared by steeping loose tea leaves in hot water for an optimal length of time and then straining the brew before consuming it. The tea infuser became popular in the mid-1800s. These encase the leaves in a wire mesh or perforated metal ball and can be removed from the water at the right time.

The first patent for a tea bag was issued to Roberta C. Lawson and Mary Molaren of Milwaukee, Wisconsin—their “Tea Leaf Holder”—on August 26, 1901. According to their application, the practice of spooning loose tea leaves into a pot “involves the use of a considerable quantity of tea leaves to prepare the desired supply of tea, and the tea, if not used directly, soon becomes stale and wanting in freshness, and therefore unsatisfactory, and frequently a large portion of the tea thus prepared and not used directly has to be thrown away, thus involving much waste and corresponding expense.”

Lawson and Molaren’s solution was very similar to modern tea bags. The tea leaf holder was made of a sleeve of loosely woven cotton fabric folded over on itself, with the flap fastened on top. The single-serving packet of tea was placed in a cup and hot water poured over it to produce “only a cup of tea fresh for immediate use.” They were granted U.S. Patent 723,287 on March 24, 1903, but they were unable to market their invention on a large scale.

In 1908, merchant Thomas Sullivan decided to save money by packaging tea samples in small silk bags instead of metal containers. The bags were intended to be emptied before brewing the tea, but his customers found it easier to infuse the tea directly with the bag and then discard the bag of spent tea. Sullivan later began using more porous gauze fabric.

Innovations over the next century made it more convenient to brew an inexpensive cup of tea. In 1930, the Salada Tea Company purchased William Hermanson’s patent for a heat-sealed paper tea bag, which eliminated the need for stitching or gluing the bags. In 1952, the Lipton Tea Company patented its “Flo-Thru” tea bag with a double-chambered bag that decreased brewing time by increasing the surface area between the tea and water.

Today, tea bags are used in 65 percent of American households. In spite of their efficiency, tea drinkers debate about the advantages of using tea bags over

loose tea. Of concern is that tea bags contained crushed tea leaves rather than whole-leaf tea and that the bags are not large enough for whole-leaf tea to expand properly. Premium tea companies have improved flavor by packaging tea in silk fabric bags, which may be hand sewn as well. Fillings include whole-leaf tea enhanced with herbs, spices, and dried fruits.

Lynda C. Titterington

See also *Vol. 1, Sec. 1: Food Production, Native American*

Further Reading

Begley, S. C. 2015. “A Brief History of the Tea Bag.” Time.com. <http://time.com/3996712/a-brief-history-of-the-tea-bag/>, accessed August 29, 2018.

Dubrin, B. 2010. *Tea Culture: History, Traditions, Celebrations, Recipes & More*. Watertown, MA: Charlesbridge.

Stone, S. 2015. “How the Tea Bag Was Invented.” <http://gizmodo.com/how-the-tea-bag-was-invented-1700351584>, accessed August 29, 2018.

Telephone

Although Alexander Graham Bell (1847–1922) was credited as the inventor of the telephone, a device that sends and receives sound such as voice messages and data across great distances, it was the product of the work of many scientists and inventors. Early attempts to create a viable telephone were based on existing telegraph technology and a desire to improve it.

Bell was the first to secure a patent for the telephone. However, Bell suffered many legal challenges to the legitimacy of his claim. But he successfully defended his patent, and, with the help of several financial backers, the company he formed became one of the largest corporations in world. The telephone industry produced many innovations that enhanced the telephone as well as other areas of endeavor. In short, telephone technology transformed the world in so many ways that life without it soon seemed inconceivable.

Like his father, Bell was a teacher of the deaf. He had a strong enough foundation of acoustics and

speech to secure employment as a teacher at Boston University in 1873, two years after emigrating from Scotland. But he was not trained as a mechanical scientist or an inventor. He knew little about mathematics, physics, or engineering. The telephone was the first device he attempted to invent. In fact, his interest in inventing began in 1872 when he attended a lecture at the Massachusetts Institute of Technology (MIT) on experimental mechanics delivered by Professor Charles R. Cross. After the lecture, Bell struck up a friendship with Cross, and for several years, the two men collaborated.

Bell made friends with two influential residents: Thomas Sanders (a wealthy merchant) and Gardiner Green Hubbard (a businessman and politician). Bell convinced Sanders and Hubbard to fund his research. They provided him a workshop, and they paid the salary of a skilled assistant named Thomas Augustus Watson (1854–1934). According to patent requirements at that time, applicants did not have to produce a working model. Instead, Patent Office officials based their acceptance or rejection of applications based on known technical knowledge. After his patent was granted in 1876, it took Bell an additional three years to improve his prototype to the level he had proposed in his application.

The two major discoveries required for the invention of the telephone were electromagnetism and induction. Scientists had known about these forces for about half a century before Bell secured a patent. In 1820, Hans Oersted (1777–1851), a Danish scientist, discovered the properties of electromagnetism, and in 1831, Michael Faraday (1791–1867), a British scientist, discovered induction.

The first recorded use of these forces to transmit and receive sound happened by chance. Antonio Meucci (1808–1889), an Italian caregiver, built a machine that used electric shocks to allegedly treat various illnesses. In 1849, while treating a man with migraines, Meucci placed a copper electrode in the patient's mouth and another in his own mouth to gauge the strength of the current. When the patient yelled, Meucci felt the sound via the electric vibration of his own electrode. Meucci filed a caveat at the U.S. Patent Office for his discovery of "Physiophony" (sound projected from a human body

through wires). The caveat gave him patent priority for one year. However, he failed to develop a practical prototype, and his caveat lapsed.

By the 1850s, long-distance communication could only be achieved through the use of the newly invented telegraph. There had never been anything like it. For the first time in human history, people were able to communicate over long distances within a matter of minutes. Unfortunately, the technology had some notable drawbacks. For example, to send a message, a trained specialist had to code and tap the message out in Morse code (a system of dots and dashes). In like manner, for the message to be successfully received, another trained specialist was required to listen to and decipher the code. Building on electric telegraph technology in 1854, Frenchman Charles Bourseul (1829–1912) published a seminal article in *L'Illustration*, a French journal, where he theorized about the possibility of transmitting intelligible spoken words with the use of electric wires. If this were possible, the long-distance communication system would become a lot less cumbersome.

In 1860, Philipp Reis (1834–1874), a German science teacher, built a device intended to transmit sound with the use of electricity. Reis's "Telephon" was said to use the power of sound waves to vibrate a parchment that produced loose contact between two platinum plates. The vibrations produced an electric signal that then traveled through a wire to a resonating receiver box. Witnesses claimed that they heard Reis's device successfully transmit and receive speech and music. In fact, for the next quarter of a century, many Germans believed that Reis had invented the telephone.

In 1874 (the year Reis died), Elisha Gray (1835–1901), an American electrical engineer, started working on a "harmonic telegraph," which he hoped would transmit several telegraph messages simultaneously at different pitches. During his experiments, Gray became convinced that his device had the potential of also transmitting spoken words, and on February 14, 1876, he applied for a caveat. Bell applied for a patent for his own "harmonic multiple telegraph" on the same day. Bell was awarded the patent (good for 17 years), but there was some controversy over who had applied first that day. The long history of the development of

telephone technology and the patent controversy led to more than 600 lawsuits over the next two decades. Bell won all of the cases.

In one of the highest-profile cases, the Reis family sued Bell for stealing the rights to telephone technology. The court found in favor of Bell's patent for two main reasons. First, Reis's notes revealed that he did not understand the workings of his own invention. His notes stated that his transmitter operated by "making and breaking" electrical contact when, in fact, the device contained a loose-contact microphone that was set up to send an undulating current. Second, and most important, the Reis camp was unable to get the device to work during the trial. In contrast, Bell was well versed in the workings of his own device, and he was able to demonstrate it at will. Ironically, in 1946, 24 years after Bell's death, an examination of Reis's prototype by an expert from Standard Telephones and Cables (STC) showed that it suffered from low amplification but that it was capable of producing intelligible speech when connected to a modern receiver.

The most serious challenge to Bell's patent was launched by Western Union (WU), which employed Thomas Edison and Elisha Gray to develop a competing telephone and telephone system. WU operated on the notion that Gray—not Bell—was the true inventor of the telephone. WU developed the first telephone switchboard and the first telephone directory. Seeking to stamp out his most aggressive competitor, Bell sued WU for patent violation and won.

With financial backing from Sanders, Hubbard, and others, Bell launched the Bell Telephone Company (BTC) in 1876. The first commercial telephone that BTC introduced a couple of years later was housed in a wooden box. It had a mouthpiece that doubled as an earpiece and a thumper to signal incoming calls. Without competition, the National Bell Telephone Company (NBTC), founded in 1879, grew rapidly. NBTC began by providing telephone services at high rates to businesses in large cities and later to residential customers. By 1880, NBTC had more than 60,000 customers in the United States alone.

In England, Edison took the lead with the telephone industry. However, within a few years, Bell and Edison's interests in England merged. Mostly due to the constant lawsuits that had taken a toll on him, Bell

retired from the telephone industry a very wealthy man in 1881. During his retirement years, he spent his time designing and building flying machines. When Bell died in 1922, AT&T paid tribute to him by disabling telephone ringers across the nation for one minute.

Void of an existing infrastructure, the primitive nature of telephone technology required many telephone line connections. Within a couple of years, the street-level skylines of large cities like New York were considered ruined by unsightly, spider web-like telephone wire formations. The first solution was to install lines underground. While crews were busy digging up city streets, NBTC came up with a second and more economical solution. NBTC borrowed WU's switchboard idea, which dramatically reduced the number of required lines.

NBTC's use of switchboards created employment opportunities for thousands of women. In 1885, NBTC also established the American Telephone and Telegraph Company (AT&T) to provide the first nationwide long-distance network. NBTC went through several transformations and name changes until it was absorbed by AT&T in 1899. For many reform-minded journalists, by the late 1800s, the AT&T corporation had come to represent greed, poor quality, and terrible customer service. However, in the early 1900s, financier J. P. Morgan (1837–1913) transformed the company into a model for modern corporations.

To keep costs down and maximize profits, in 1914, AT&T formed alliances with a variety of companies from around the world that produced low-cost telephone equipment. To foster innovation in telephone technology and stay ahead of other competing telephone companies in the 1940s, AT&T created Bell Labs. In 1948, Bell Labs created the transistor, which replaced the vacuum tube in telephone networks. Compared to vacuum tubes, transistors were less expensive and much smaller. In 1956, Bell Labs was awarded the Nobel Prize for the introduction of the transistor, which had applications far beyond telephone use. Bell Labs developed cellular phone wireless technology (1947), the computer modem (1957), and communication satellites (1962) that orbited the earth and facilitated worldwide telephone communications.

In 1965, the development of electronic switching systems permitted a vast increase in telephone traffic

and also set the stage for later Internet traffic. By the 1980s, AT&T employed more than 1 million people. The federal courts ruled that AT&T was a monopoly and ordered that it be dismantled. In 1984, when it was broken up, the company's assets totaled about \$155 billion, which was more than the assets of General Motors, Mobil, and Exxon combined.

The telephone transformed society. It changed the way that business was conducted. For example, customers could save on travel expenses and time by calling stores to find out if certain items were in stock or by quickly making price comparisons. In like manner, the telephone changed the way that medicine was practiced. The telephone could instantly link patients, doctors, and pharmacies. Certainly, the speed with which emergency and rescue crews could provide services was greatly enhanced by the advent of telephones. Telephones changed the way that businesses were run. Since the telephone allowed salespeople to report to their bosses and get orders from them from long distances, they were able to function on a regional and national level.

The social influence of telephones was also extremely profound. The telephone allowed families and acquaintances who were separated by great distances to speak to each other. It also allowed them to communicate more often than ever before. In a powerful way, the telephone dissolved distance. For example, it connected rural and farm areas with cities and urban centers. It allowed people from different nations to speak to each other at the speed of light. Cellular phones, which connected wirelessly to the Internet, allowed users to access a variety of information, including sports scores, soap opera updates, and up-to-date bank balances. It did not take long for people to become accustomed to the luxury of telephone technology. In fact, most people soon found it difficult to conceive of life without a telephone—a condition exasperated by the invention of the mobile or cell phone.

Rolando Avila

See also *Vol. 1, Sec. 3*: Telegraph; *Vol. 2, Sec. 1*: American Telephone and Telegraph Company (AT&T); Bell, Alexander Graham; Edison, Thomas; *Vol. 3, Sec. 1*: Telephone Switching, Computerized; *Vol. 3, Sec. 2*: Mobile Phone

Further Reading

- Bigelow, Stephen J. 2001. *Understanding Telephone Electronics*. Boston: Newnes.
- Brooks, John. 1976. *Telephone: The First Hundred Years*. New York: Harper & Row.
- Noll, A. Michael. 1999. *Introduction to Telephones and Telephone Systems*. Norwood, MA: Artech House.
- Wasserman, Neil H. 1985. *From Invention to Innovation: Long Distance Telephone Transmission at the Turn of the Century*. Baltimore: Johns Hopkins University Press.

Television

Television technology, a system for transmitting and receiving both visual images and sound, was developed and improved by many people. Television technology operates on two major principles. First, the human brain has the ability to reassemble dots (pixels) into images. Second, the human brain can view a series of successive pictures and from them, form a single flowing image. Both early rival television designs capitalized on these two human traits.

Although the popularity of electronic television technology began slowly, after prevailing over mechanical television technology, electronic television quickly became a fixture in American life after 1945. In fact, it has made an indelible mark on American daily life, culture, and politics. Improvements in picture quality (including color and high definition) and functionality (including compatibility with peripherals) served to foster America's fascination with television.

Paul Nipkow (1860–1940), a German engineer, was the first to patent a type of early television technology in 1884. Nipkow's mechanical design employed a disk with holes that spiraled through it. When light was projected through the spinning disk, it produced images on a photosensitive cell. In truth, Nipkow never constructed a physical model of his theoretical design. However, his idea inspired many other inventors. The Scottish inventor John Logie Baird (1888–1945), for example, unveiled his mechanical disk design to the public in 1925. At that time, Baird's television technology was able to transmit and

receive crude patterns of light and dark to represent images. By 1929, Baird's improvements to image quality were so great that the British Broadcasting Corporation (BBC), a major European radio company, allowed him to conduct experiments using its transmitters. American inventor Charles Francis Jenkins (1867–1934) also based his work on Nipkow's design.

After several years of development, Jenkins received the first American television broadcasting license from the Federal Radio Commission in 1928, which allowed him to conduct experimental transmissions in Washington, D.C. Two years later, Jenkins rolled out his television for sale to the public. Jenkins's low-definition set had a 2 x 1.5-inch (5.08 x 3.81 cm) viewing screen with only 48 horizontal imaging lines. Independent inventors like Baird, Jenkins, and others were soon outmatched by groups of scientists employed by big corporations—including General Electric (GE), American Telephone & Telegraph (AT&T), and Radio Corporation of America (RCA)—who quickly churned out mechanical televisions. Television sales got off to a slow start, mostly due to a shortage of available television programming and broadcasting.

The need to fill television airtime created opportunities for aspiring actors and some famous radio actors who capitalized on the situation by moving to the new medium. Radio sponsors were captivated by the ability to advertise their products with both sound and images on television. For this reason, many entrepreneurs believed that the new medium had great potential.

Mechanical television technology received competition from a revival of earlier television technology. Since the early 1900s, several scientists had theorized about and experimented with electrochromic television technology, which employed a transmitting tube to project images onto a photosensitive array and then displayed them through a modified cathode ray tube. Russian scientist Vladimir Zworykin (1889–1982) secured corporate financial backing to make this technology a viable consumer product. In 1919, Zworykin emigrated to the United States and developed the iconoscope system while he worked for Westinghouse and later for RCA.

American independent inventor Philo Farnsworth (1906–1971), who has been credited as the inventor of

electric television, developed his own “improved” version of the electronic television system and held a public demonstration of his image-dissector tube system in 1934. However, sales of Farnsworth's set paled in comparison to Zworykin's RCA-backed machine. Mechanical and electronic television sets required broadcasts tailored to their exclusive designs. Rather than send two different kinds of broadcasts, Britain switched its broadcasting to electronic in 1936. The standardized broadcast signal convinced many British citizens to purchase electronic sets. However, just as the British television industry was gaining momentum, the BBC stopped all television broadcasts after the outbreak of World War II (1939–1945).

Before the war, Germany utilized television technology for the purpose of propaganda that promoted the idea of superiority. The 1936 Olympics held in Berlin was the first to be televised. The grandeur of the event on display for the world to see influenced the way all future Olympics were staged. Electronic televisions sported a larger screen and clearer image reproduction than did mechanical televisions. For these reasons, electronic televisions quickly gained in popularity over mechanical televisions by the mid-1930s in the United States.

The last recorded broadcast of a mechanical television signal was to a small remaining market in 1939. Even though electronic televisions had become the standard by the late 1930s, each U.S. corporation produced unique electronic television sets that required specialized broadcasts. Some American consumers remained hesitant to invest in any particular brand of television set for fear that it might become obsolete by a standardization of the broadcast signal. In 1941, the Federal Communications Commission (FCC) passed standards that insured the compatibility of all new television receivers with all television broadcast signals. However, American entrance into World War II in December of that year stagnated developments in the American television industry for the next four years.

After the war, the popularity of television eclipsed the popularity of radio. The number of television stations exploded. In fact, so many new television stations were created that in 1948, the FCC was forced to freeze the assignment of new station assignments because the clutter of new stations was creating

interference. It took the FCC four years to research, plan, and carry out new station assignments. After the FCC lifted the freeze in 1952, the flow of new stations started up once again.

Another conflict related to color broadcasting arose in 1949 between Columbia Broadcasting System's (CBS) field-sequential color system and RCA's dot-sequential color system, which were incompatible. After four years of hearings, the FCC mandated dot sequential as the standard color broadcasting system. In spite of the station assignment freeze and the color controversy, American television set sales continued to rise from 16,000 in 1947 to 4 million in 1949 to 11 million in 1950.

By the 1950s, television was the most popular household item. Television viewers were captivated by various forms of programs, including game shows, variety shows, serial dramas, and situation comedies. The *I Love Lucy Show* (1951–1957) was the decade's most popular comedy. In a time before technology to record programs was available to the public, viewers had to tune in if they wanted to see for themselves what funny situation the character of Lucy Ricardo (played by comedian Lucille Ball) would get herself involved in each week. In some cities, retail stores routinely closed early during the show's broadcast due to lack of customers. In large cities, the crime rate fell during the show's half-hour slot.

Television had a great influence on American daily life and culture. Advertisers influenced American choices in many aspects of life, including food, dress, cars, and music. Many teenagers tuned in to *American Bandstand* to learn the latest dance steps and to listen to the latest music. With allowances in hand, they would then rush to stores to buy records of the week's hit songs. The practice created a market for performers like Elvis Presley in the 1950s and the Beatles in the 1960s.

By the mid-1960s, the sale of color television sets outnumbered the sale of black-and-white sets. By that time, color broadcasting had become routine and about 9 out of 10 households had at least a black-and-white or color set. Besides the main driving force of the entertainment value of television, viewers also relied heavily on television news and other information. Throughout his career, television reporter Walter

Cronkite (1916–2009) gained respect and trust from many viewers.

In the 1950s, Senator Joseph McCarthy gained great political influence when he launched a witch hunt against people he claimed were communists who had infiltrated the U.S. government. During the so-called Second Red Scare, television reporter Edward R. Murrow exposed McCarthy as a fraud and helped destroy his reign of fear. During the first televised presidential debate between Richard Nixon and John F. Kennedy in 1960, the majority of television viewers reported that Kennedy had won the debate while those who listened to the same debate on the radio believed that Nixon had done better. Some historians pondered whether the homely Abraham Lincoln (1809–1865), who has been ranked by several polls as the best American president, would have been elected if he had lived during the television age. Political scientists wrote about the new visual dimension that television had forever introduced into politics. From that moment on, how a politician looked and how he or she moved would play a major role in who people voted for. Television technology also allowed people to view historic events as they happened. For example, in 1969, viewers witnessed the moon landing, and in 1989, they saw the fall of the Berlin wall.

Antennas wired to home television receivers had been the exclusive norm for most of television's history, but during the late 1970s, home satellite receivers had also appeared in some homes. By the 1980s, the three most powerful television networks were CBS, the National Broadcasting Company (NBC), and the American Broadcasting Company (ABC). In 1983, the final episode of *M*A*S*H* was seen on CBS by the highest recorded television audience in history of 125 million (77 percent of the audience share). Since 1967, the Public Broadcasting System (PBS) has offered viewers publicly supported alternative choices of programming in education, British dramas, and news. In the 1980s, cable companies, which sent signals to homes through coaxial cable from a central station antenna, also offered paying subscribers premium viewing choices.

In 1996, American broadcasters began displaying ratings of programs (such as TV-G for “general audiences,” TV-PG for “parental guidance suggested,”

TV-14 for “unsuitable for children under 14,” and TV-MA for “mature audiences only”). CBS and ABC also added V (violence), S (sex), L (coarse language), and D (suggestive dialogue) to their rating systems. Based on these rating systems, some television manufacturers imbedded a “V-chip” to allow parents to block programs they deemed inappropriate.

Standard-definition television screens typically had about 600 horizontal lines of dots (pixels). In recent years, the American government mandated a migration of all television broadcasting and receivers from analog to digital signal format, which delivered content in much sharper and clearer resolution. Plasma and liquid crystal display (LCD) television sets were made without cathode ray tubes. The lack of a tube enabled manufacturers to design thinner (or flat) screens for these televisions, which could be mounted on walls. These tubeless television screens contained electronically charged ions and electrons that bumped into one another when an electrical signal was introduced. The bumping created photons (glowing lights) that created screen images.

Manufacturers also rolled out big-screen, high-definition (HD) advanced television (ATV) sets, as well as sets that displayed three-dimensional images, capable of wireless convergence between computers and Internet content. By the 2000s, some HD sets contained 1080 x 500 pixels. The added pixels produced visually rich (almost lifelike) images. America’s love of television has not waned since its introduction. In 2005, the average American spent from two to five hours each day watching television.

Rolando Avila

See also *Vol. 2, Sec. 2: Radio*

Further Reading

- Abramson, Albert. 1987. *The History of Television, 1880–1941*. London: McFarland.
- Fisher, David E. 1996. *Tube: The Invention of Television*. Washington, D.C.: Counterpoint.
- Ritchie, Michael. 1994. *Please Stand By: A Prehistory of Television*. Woodstock, NY: Overlook Press.
- Trundle, Eugene. 2001. *Newnes Guide to Television and Video Technology*. Boston: Newnes.

Tennessee Valley Authority Electricity Project (TVA)

The Tennessee Valley Authority Electricity Project, also known as the TVA, is a federally owned U.S. corporation chartered through the TVA Act on May 18, 1933. Signed off on by President Franklin Delano Roosevelt, fervently backed by Nebraska senator George Norris, and inspired as a solution to the economic woes of the Great Depression, the TVA was created in alignment with the New Deal with the purpose of controlling floods along the Tennessee River, electric power generation, navigation, reforestation, prevention of soil erosion, and modernization of the greater general region. The corporation’s goal, in terms of power generation, was clear. It aimed to provide a reliable stream of electricity at wholesale rates to its customers. The corporation would also serve as a model in which privately owned utility companies could be measured and judged for their effectiveness and competitiveness in the market.

Upon its initial formation, the TVA obtained the Wilson Dam located in Muscle Shoals, a newly incorporated town in Alabama and perfectly positioned along the Tennessee River. Wilson Dam would serve as the TVA’s primary source of power generation during the corporation’s early development. But electricity was scarcely needed within the vicinity of Wilson Dam, which prompted the TVA to look for other markets to sell to.

The TVA was able to successfully generate the bulk of its first few years of income by acquiring transmission and distribution facilities from the Mississippi Power Company to sell to the Alabama Power Company. Between July 1934 and February 1935, the TVA sold \$294,712 worth of electricity. A new fleet of hydroelectric generating stations, including Norris, Wheeler, and Pickwick Landing Dams, were under construction and due to open before the start of the 1940s.

The Second World War further stimulated a need for power production to manufacture weapons and planes. The aluminum industry and Oak Ridge National Laboratory placed a large need for power on the TVA. In response, 12 hydroelectric plants and one steam plant were readily constructed, thus supplying

the energy necessary to meet these demands. TVA's cheap electric rates made the Tennessee Valley a fertile location for industrial growth. This strengthened the economic climate of the region as more jobs became available, drawing larger populations and new businesses. Due to the construction of TVA's new facilities alone, roughly 28,000 jobs were created.

By the 1950s, the TVA had become the largest supplier of electricity in the United States. The region continued to see growth even after the war ended. No longer capable of meeting the demand for electricity, the TVA looked to coal-fired steam plants as a solution. This marked an important period for the TVA as it successfully sought financial independence, allowing it to issue bonds to build and obtain more plants. It not only bought a few coal-fired plants from utility companies but had begun constructing its own as early as 1942, with the Watts Bar Steam Plant being the first. Watts Bar was capable of generating 267 MW, but that wasn't enough. In total, the TVA built seven coal-fired plants, predominantly in Tennessee and Alabama, during the 1950s that together produced over 3,770 MW of power. The Widows Creek Fossil Plant's Unit 7 was generating an impressive 500 MW of power, at the time the largest of its kind in the world.

In 1966, TVA sought to continue its expansion of electric generating stations by constructing its first nuclear generating plant—Browns Ferry, near Athens, Alabama. Browns Ferry Plant made world history with its three boiling reactors producing over 1 billion watts of power by 1976. Plans had initially called for several more nuclear stations, but the oil embargo of 1973 caused electricity rates within the TVA to skyrocket as much as five times higher than its normal rate.

The TVA went through a drastic period of restructuring its organization, which led to the cancelation of many nuclear construction projects. After successfully rebounding from the effects of the oil crisis, the federal corporation soon began to focus on clean energy and economic development. In 2000, it launched the Green Power Switch program, a program dedicated to introducing more renewable energy into the electric grid. In 2011, the TVA, in agreement with the Environmental Protection Agency (EPA), committed to retiring 18 of its 59 coal-fired plants by 2017. Between

2005 and 2013, TVA reduced 32 percent of its carbon dioxide emissions.

As of 2017, the TVA stands as the United States' largest government-owned power provider. In 2016, the revenue produced by its power production and distribution reached approximately \$10.5 billion. The TVA receives no tax dollars, and its profit is reinvested into providing better quality power production as well as into community development programs. The TVA boasts a wide range of production facilities, including 29 hydro plants, 14 solar energy sites, 9 natural-gas-combustion turbine plants, 8 fossil plants, 7 natural gas combined-cycle plants, 3 nuclear plants, 1 pumped-storage hydroelectric plant, 1 diesel-generator site, and 1 wind-energy site. Its energy production is capable of 169,000 gigawatt-hours. Of this energy produced, 37 percent comes from nuclear, 24 percent coal, 20 percent natural gas, 9 percent hydro, 3 percent wind and solar, and 7 percent energy efficiency.

Jonathan G. Herrera

See also *Vol. 2, Sec. 2: Hydroelectric Power; Vol. 3, Sec. 2: Nuclear Energy/Nuclear Power Plants; Solar Energy*

Further Reading

Mason, Edward S. 1936. "Power Aspects of the Tennessee Valley Authority's Program." *The Quarterly Journal of Economics* 50, no. 3: 377–414. <http://www.jstor.org/stable/1882609>, accessed August 29, 2018.

"Power for Peacetime." TVA—Home. <https://www.tva.gov/>, accessed August 29, 2018.

"The Tennessee Valley Authority Act." 1934. *The Yale Law Journal* 43, no. 5: 815–26.

Thomas, Vivien Theodore (1910–1985)

Vivien Theodore Thomas was an African American laboratory technician; educational instructor at Johns Hopkins University, Baltimore; and an innovator of cardiac surgery. His most notable recognitions include contribution to the discovery of the cause of traumatic shock and developing the procedure for and guiding the first operation to treat tetralogy of Fallot, commonly

known as the “blue baby syndrome” responsible for the deaths of thousands of children every year. Other accomplishments include aiding in the development of the electrical defibrillator and executing the first atrial septectomy.

Thomas was born the grandson of a slave on August 29, 1910, in New Iberia, Louisiana. In his early years, Thomas worked as a carpenter alongside his father. At age 19, he graduated with honors from Pearl High School in Nashville, Tennessee. He then began to pursue his dream of becoming a doctor and enrolled in a premedical course at the Tennessee State Agricultural and Industrial College in Nashville. Due to the financial hardships brought on by the Great Depression, Thomas was forced to put his college career on hold and seek employment.

On February 10, 1930, Thomas applied for a laboratory assistant position at Vanderbilt University Medical School. At Vanderbilt, he was introduced to Dr. Alfred Blalock, his mentor and employer. This marked the beginning of a partnership that achieved medical and scientific breakthroughs. From the beginning, Thomas immersed himself in the studies of Blalock’s research, countless textbooks, and learned anatomy from Dr. Joseph Beard (1901–1983). Thomas would often work late hours with Blalock, and they would share each other’s findings and research as well as enjoy alcoholic beverages together, which was not acceptable to society at the time due to Thomas’s African American background.

In 1933, Blalock presented his theory of traumatic shock to the Chicago Surgical Society that had been developed in his experiments with Thomas. Traumatic shock was the leading cause of death in surgical procedures. Their theory claimed that one of its major causes was blood loss. Blalock and Thomas had an unparalleled partnership. In 1937, Blalock rejected an offer of employment at Henry Ford Hospital in Detroit because it did not permit African American employees.

In 1943, Dr. Helen Taussig, who was one of the first recognized female pediatric cardiologists, reached out to Blalock for a surgical solution to the tetralogy of Fallot/blue baby syndrome. With Thomas’s assistance, they were able to draft the first procedure to treat blue baby syndrome. Blalock and Thomas executed its first-ever operation on Eileen Saxon (1942–1945), one

of Taussig’s patients who was in extremely critical condition. The operation was successful and extended Eileen Saxon’s life past previous expectancy, but unfortunately, she died less than a year later.

More operations were conducted shortly afterward, which brought great fame and recognition to Blalock and Taussig for their surgical breakthrough. In today’s operation, a similar tool called the “Blalock clamp” is used. This surgical breakthrough has saved millions of lives since its original discovery, which wouldn’t have been possible without the assistance of Thomas’s research.

These discoveries in blue baby syndrome solutions brought fame and recognition to Johns Hopkins University. It became Vivien Thomas’s unofficial responsibility to instruct in surgery at the university; he taught students surgical procedures that contributed to the newly developed field of cardiac and cardiovascular surgery.

Thirty years after Thomas first entered the doors of Johns Hopkins University, a portrait of him was commissioned to recognize his achievements, the first portrait of an African American to be hung in the university’s halls. It was displayed alongside those of the university’s presidents and professors.

On May 21, 1976, Thomas received an honorary doctorate from Johns Hopkins University. In the following year, he was officially appointed to the faculty of Johns Hopkins and granted the position of instructor of surgery.

Thomas served as an African American icon and leader in the Johns Hopkins community. His students Richard Scott (1941–present) and Levi Watkins (1944–present) became the university’s first official black surgical resident and first black cardiac resident. Thomas’s final research project was conducted alongside his apprentice, Levi Watkins, which led to the first human implantation of the automatic implantable defibrillator.

Emma E. L. Burke

See also *Vol. 1, Sec. 2:* Rush, Benjamin; *Vol. 2, Sec. 2:* Drew, Charles; *Vol. 3, Sec. 1:* Taussig, Helen

Further Reading

Joyner, Alisha, Charles J. Yeo, I. V. Maxwell, and J. Pinckney. 2015. “Vivien Thomas.” *American Surgeon* 81, no. 2 (February): 118–20.

- Ng, Chin Ting Justin. 2014. "Vivien Thomas." *Journal of Investigative Surgery* 27, no. 3 (June): 131–38.
- Snyder Whitehurst, Lucinda. 2016. "Vivien Thomas." *School Library Journal* 62, no. 5 (May): 132–32.
- Soylu, Erdinc, Thanos Athanasiou, and Omar A. Jaral. 2017. "Vivien Thomas." *Journal of Medical Biography* 25, no. 2 (May): 106–13.

Tizard Mission

The Tizard Mission was the informal name given to a British delegation that came to the United States in 1940 seeking support for the development of British technical innovations. Britain hoped to exploit British innovations in the war against Germany and Italy. Formally known as the British Technical and Scientific Mission, the mission became known as the Tizard Mission after Henry Tizard, the man who organized the endeavor.

While the United States formally declared war in December 1941, England had gone to war against Axis powers in 1939. The United States had officially been neutral between 1939 and 1941, but President Franklin D. Roosevelt and other leaders in the federal government were not averse to helping England. To this end, a British delegation came to the United States in September 1940. The mission shared British technological innovations, including radar, jet engine improvements, and atom bomb science.

Because many members of the U.S. Congress opposed overt cooperation with the British, fearing a breach in American neutrality, Tizard shared technological information with American scientist Archibald Hill, who then advocated for the mission in Washington.

Mission members included representatives of the British Army, Royal Navy, Royal Airforce, Army Research, and a scientist specializing in radar. Members of the mission toured General Electric Labs, met with Enrico Fermi at Columbia University and members of the U.S. Army, including General "Hap" Arnold, who would oversee the Women Airforce Service Pilots (WASPs) from 1942 to 1944.

Though the Tizard Mission is now considered a success, Henry Tizard returned to London to find that his job no longer existed. After the war, he would lead

a research project into the existence of unidentified flying objects (UFOs).

Peg A. Lamphier

See also Fermi, Enrico; Radar; Women's Airforce Service Pilots (WASPs); *Vol. 3, Sec. 3: SETI (Search for Extraterrestrial Intelligence)*

Further Reading

- Phelps, Stephen. 2010. *The Tizard Mission: The Top-Secret Operation That Changed the Course of World War II*. Yardley, PA: Westholme.
- Zimmerman, David. 1996. *Top Secret Exchange and the Scientific War*. Montreal: McGill-Queen's University Press.

Women's Airforce Service Pilots (WASPs)

The energetic and enthusiastic work of two dedicated female pilots, Jacqueline Cochran and Nancy Harkness Love, resulted in the formation of the Women's Airforce Service Pilots (WASPs), the first group of military-sanctioned female pilots in the United States.

In September 1939, Cochran wrote a letter to Eleanor Roosevelt declaring that with the war in Europe (World War II) going badly, America should begin allowing women to fly noncombat missions to free the men for overseas duty. She received a polite and supportive response from the first lady but knew that the decision would not be up to her. In May 1940, a similar letter was sent to the U.S. Army Air Corps, Plans Division, by Love. Her letter also met with inaction.

In 1941 Cochran met with General H. H. "Hap" Arnold, chief of the U.S. Army Air Corps, and again put forth her idea. Something similar was already underway in England with the Air Transport Authority (ATA), which was taking volunteers from all countries. Arnold recommended that Cochran work with the ATA to help show the American military that women ferry pilots were a good idea. For the ATA, Cochran agreed to ferry a bomber plane from its manufacture site in North America to its base in England. After she successfully completed the mission, the U.S. government was still not convinced that its military

could benefit from such a group. Cochran put her efforts toward recruiting American female pilots for the British ATA.

On May 28, 1941, Congresswoman Edith Nourse Rogers proposed to Congress the legislation that would establish a Women's Army Auxiliary Corps (WAAC). It was stalled in Congress until after the bombing of Pearl Harbor and then was debated until the U.S. Air Force showed an interest in using the services of qualified women pilots. The bill was passed on May 15, 1942, nearly a year after it was proposed.

Love, who had moved to Washington, D.C., when her husband was called to military duty, met with his superiors at the Air Transport Command (ATC) to reintroduce the concept of women ferry pilots. The new commander, Brigadier General Harold L. George, asked Love to draft a proposal. On September 10, 1942, Love's proposal was announced in the newspapers. Women who filled the requirements were asked to apply to what was then called the Women's Auxiliary Ferrying Squadron (WAFS). Requirements for applicants included two letters of recommendation, a high school degree, and 500 hours of logged flying time. While male pilots could be between the ages of 19 and 45, female applicants had to be between the ages of 21 and 35.

When Cochran returned from her recruitment efforts for the British ATA, she was astounded to learn that an American group had been created without her. General Arnold made her the director of the Women's Flying Training Detachment (WFTD), a group organized to train novice women pilots to fulfill WAFS requirements.

In July 1943, the Pentagon combined the WAFS and the WFTD, creating the WASP. To support its efforts, Walt Disney created *Fifinella*, a female gremlin mascot for the group.

After the merger, Cochran was promoted to director of women pilots. Through her efforts, the WASP ferried larger aircraft and took positions towing targets for bombers. They also flew as check pilots on planes reported faulty by male pilots, leading to some of the few fatalities associated with the WASP program.

In February 1944, H.R. 4219 was presented in Congress to militarize the WASP and provide all the benefits of soldiers, from free uniforms to postwar

pensions. This drew angry letter-writing campaigns from male pilots who had failed to pass military tests and physicals. They wanted the duties of the WASPs to be handed to them, even though WASPs were better-qualified pilots. These complaints were considered by the House Committee of Military Affairs in March 1944 along with testimony by only one witness, General Arnold. The vote was 169 to 188. H.R. 4219 was killed in Congress on June 21, 1944.

At this time, the WASP program was also cut, allowing female pilots already in service to continue through the end of the war but denying any further training to women for the purpose of entering the WASP. A new class of trainees already en route to Avenger Field had to be sent home when they arrived. As the war in Europe seemed to be going well for the Allies, the WASP program was deactivated on December 20, 1944. There had been 1,074 female pilots in the WASP program and 38 fatalities.

In 1953, the military recalled interested former WASPs to their old posts to provide support during the Korean War.

In September 1976, the U.S. Senate finally voted to make the WASPs official veterans of World War II, partly as a result of lobbying by the WASP alumni group known as the Order of *Fifinella*. In their deactivation letters, General Arnold wrote to the WASPs, "When we needed you, you came through and have served most commendably under very difficult circumstances."

Perhaps the feel of being a WASP was best expressed by Cornelia Fort, who died on duty with the WASP. Before she died, she wrote,

As long as our planes fly overhead the skies of America are free and that's what all of us everywhere are fighting for. And that we, in a very small way, are being allowed to help keep that sky free is the most beautiful thing I have ever known. I, for one, am profoundly grateful that my one talent, my only knowledge, flying, happens to be of use to my country when it is needed. That's all the luck I ever hope to have.

Rosanne Welch

See also B-17 Flying Fortress; Curtiss-Wright Aeronautical Engineering Cadettes; Rosie the Riveter

Further Reading

Douglas, Deborah G. 1990. *United States Women in Aviation, 1940–1985*. Washington, D.C.: Smithsonian Institution Press.

Noggle, Anne. 1990. *For God, Country, and the Thrill of It: Women Airforce Service Pilots in World War II*. College Station: Texas A&M University Press.

Wu, Chien-Shiung (1912–1997)

Distinguished Chinese American experimental physicist and the “First Lady of Physics,” Chien-Shiung Wu is best known for the Wu experiment, which proved that the law of conservation of parity does not hold for weak subatomic interactions. Dr. Wu was an expert in the subject of beta decay and played an important role in the Manhattan Project.

Chien-Shiung Wu was born to Chinese parents: Zhong-Yi Wu, her father, and Funhua Fan, her mother, on May 31, 1912, in Liuhe, Taicang, Jiangsu Province, China. Her father was an engineer by training and strongly believed in equality for women. In 1913, he founded one of the first schools in China to admit girls. Wu attended her father’s school, where she showed great promise in math and science. When she was 11 years old, she left home to attend the Suzhou Women’s Normal School No. 2. Wu borrowed mathematics, physics, and chemistry books from her friends who attended the regular school program and read and studied from them at night. She graduated at the top of her class in 1929. In 1934, she received a BS degree in physics from the National Central University (NCU) in Nanjing. She taught for one year at the Zhejiang University and did two years of graduate-level study in physics as an assistant at the Academia Sinica.

In 1936, Wu took a ship to the United States with her friend Dong Ruofen. The two women arrived in San Francisco, California, and visited the University of California, Berkeley. There, Wu met physicist Ernest Orlando Lawrence, inventor of the cyclotron particle accelerator. Lawrence convinced her to attend UC Berkeley, where she would complete her PhD in physics in 1940.

In 1942, Wu married physicist Luke Chia-Liu Yuan, grandson of the first president of the new



The “First Lady of Physics,” Chien-Shiung Wu developed the process for separating uranium for the Manhattan Project to produce the first nuclear bombs. She won a Nobel Prize in physics in 1957. (Library of Congress)

Republic of China. She met Yuan at Berkeley, and it was he who convinced her to do her graduate studies there. They would have one son, Vincent Yuan, who also became a physicist. Also in 1942, Smith College offered Wu a teaching position. Smith did not have a research facility, and in 1943, Wu accepted an offer from Princeton University. She was invited to join the Manhattan District Project (Manhattan Project) at Columbia University as a senior scientist in 1944. As a Manhattan Project researcher, she developed a process that separated uranium metal into the U-235 and U-238 isotopes by gaseous diffusion. Wu’s work helped with the development of the atomic bomb.

Wu worked at the Physics Department at Columbia University until 1981, when she retired as a Michael I. Pupin Emerita Professor of Physics. In the mid-1950s, Tsung-Dao Lee and Chen-Ning Yang agreed that the law of conservation of parity had not been tested for weak nuclear force and theorized that it would not hold true for that type of subatomic

interaction. For her expertise in beta decay (she published a book titled *Beta Decay* in 1965), they asked Wu to assist them. They proved that the law of conservation of parity did not hold true for the weak nuclear force. In 1957, Lee and Yang were awarded the Nobel Prize in Physics. The Nobel Prize committee did not recognize Wu's work. However, in 1978, she received the first Wolf Prize in Physics for her experimental work on the law of conservation of parity. Wu's research included the correlation of the quantum polarizations of two photons that propagate in opposite directions, the molecular changes in the deformation of hemoglobin that cause sickle-cell disease, and work on the Mossbauer effect. She won the National Medal of Science in 1975. After her retirement in 1981, Wu devoted her time and effort to educational programs to promote female scientists, in part because of her own

struggles for recognition as a woman scientist. Wu died in New York in 1997 from a stroke and was buried in China. She is remembered as the "Queen of Nuclear Research" and the "First Lady of Physics" for her significant contributions to American science.

Mariana Magaña

See also Clarke, Edith; Lamarr, Hedy; Manhattan Project; Oppenheimer, J. Robert; *Vol. 2, Sec. 2*: Einstein, Albert

Further Reading

Byers, Nina, and Gary Williams. 2010. *Out of the Shadows: Contributions of Twentieth-Century Women to Physics*. Cambridge: Cambridge University Press.

Chiang, Tsai-Chien. 2013. *Madame Chien-Shiung Wu: The First Lady of Physics Research*. Translated by Tang-Fong Wong. Singapore: World Scientific.

Bibliography: Reconstruction through World War II

Section 1: The Rise of Industrialism,

Reconstruction, and the Gilded Age (1866–1900)

- Cadbury, Deborah. 2003. *Dreams of Iron and Steel: Seven Wonders of the Nineteenth Century, from the Building of the London Sewers to the Panama Canal*. New York: Fourth Estate.
- Carlson, W. Bernard. 2013. *Tesla: Inventor of the Electrical Age*. Princeton, NJ: Princeton University Press.
- Casson, Herbert Newton. 2006. *The History of the Telephone*. New York: Cosimo Classics.
- Cawthorne, Nigel. 2016. *Tesla vs. Edison: The Life-Long Feud that Electrified the World*. New York: Chartwell Books.
- Cooper, Christopher. 2015. *The Truth about Tesla: The Myth of the Lone Genius in the History of Innovation*. New York: Quarto.
- Cory, William. 2010. *Fans and Ventilation: A Practical Guide*. Amsterdam, Netherlands: Elsevier.
- Daly, Michael. 2013. *Topsy: The Startling Story of the Crooked-Tailed Elephant, P. T. Barnum, and the American Wizard, Thomas Edison*. New York: Atlantic Monthly Press.
- Gordon, John Steele. 2004. *An Empire of Wealth. The Epic History of American Economic Power*. New York: Harper Collins.
- Gray, Charlotte. 2011. *Reluctant Genius: Alexander Graham Bell and the Passion for Invention*. New York: Arcade.
- Grosvenor, Edwin S., and Morgan Wesson. 2016. *Alexander Graham Bell*. New York: New Word City.
- Gustavson, Todd. 2009. *Camera: A History of Photography from Daguerreotype to Digital*. New York: Sterling.
- Jinks, Beth. 2013. "Kodak Moments Just a Memory as Company Exists Bankruptcy." Bloomberg. September 3. <https://www.bloomberg.com/news/articles/2013-09-03/kodak-exits-bankruptcy-as-printer-without-photographs>, accessed August 27, 2018.
- Jonnes, Jill. 2004. *Empires of Light: Edison, Tesla, Westinghouse, and the Race to Electrify the World*. New York: Random House.
- Marcot, Roy M. 2002. *Spencer Repeating Firearms*. n.p.: Andrew Mowbray.
- McCullough, David. 2012. *The Great Bridge: The Epic Story of the Building of the Brooklyn Bridge*. New York: Simon & Schuster.
- McMurry, Linda O. 1994. *George Washington Carver: Scientist and Symbol*. Norwalk, CT: Easton Press.
- Millard, Andre J. 2005. *America on Record: A History of Recorded Sound*. 2nd ed. New York: Cambridge University Press.
- Nasaw, David. 2007. *Andrew Carnegie*. New York: Penguin Books.
- National Center for Asphalt Technology. 2009. *Hot Mix Asphalt Materials, Mixture Design, and Construction*. 3rd ed. Auburn, AL: Auburn University.
- Romano, Frank. 2014. *History of the Linotype Company*. Rochester, NY: RIT Press.
- Schaurchburg, Richard P. 1993. *Carriages without Horses: J. Frank Duryea and the Birth of the American Automobile Industry*. Orlando, FL: Society of Automotive Engineers.
- Shephard, Sue. 2006. *Pickled, Potted and Canned: How the Art and Science of Food Preserving Changed the World*. New York: Simon & Schuster.
- Steffen, David J. 2005. *From Edison to Marconi: The First Thirty Years of Recorded Music*. Jefferson, NC: McFarland.

Stross, Randall. 2007. *The Wizard of Menlo Park: How Thomas Alva Edison Invented the Modern World*. New York: Crown.

Waples, David A. 2012. *The Natural Gas Industry in Appalachia: A History from the First Discovery to the Tapping of the Marcellus Shale*. Jefferson, NC: McFarland.

Weingardt, Richard. 2009. *Circles in the Sky: The Life and Times of George Ferris*. Reston, VA: American Society of Civil Engineers.

Section 2: The Progressive Era and the Roaring Twenties (1900–1929)

Ambrose, Tom. 2013. *A History of Cycling in Fifty Bikes: From the Velocipede to the Pinarello, the Bicycles That Have Shaped the World*. Emmaus, PA: Rodale Books.

Boyd, Thomas Alvin. 2002. *Charles F. Kettering: A Biography*. Philadelphia: Beard Books.

Braun, Sandra. 2007. *Incredible Women Inventors: Women's Hall of Fame Series*. n.p.: Second Story Press.

Bunn, Geoffrey C. 2012. *The Truth Machine: A Social History of the Lie Detector*. Baltimore: Johns Hopkins University Press.

Curcio, Vincent. 2013. *Henry Ford*. New York: Oxford Press.

Gertner, Jon. 2012. *The Idea Factory: Bell Labs and the Great Age of American Innovation*. New York: Penguin Press.

Hawking, Stephen, and Leonard Mlodinov. 2010. *The Grand Design*. New York: Bantam.

Heller, Vivian, ed. 2004. *The City Beneath Us: Building the New York Subways*. New York: W. W. Norton.

Isaacson, Walter. 2008. *Einstein: His Life and Universe*. New York: Simon & Schuster.

Keith, Michael C. 2000. *Talking Radio: An Oral History of American Radio in the Television Age*. Armonk, NY: M. E. Sharpe.

Kenney, William Howland. 2003. *Recorded Music in American Life: The Phonograph and Popular Memory, 1890–1945*. Oxford: Oxford University Press.

Kruger, David Delbert. 2017. *J. C. Penney: The Man, the Store, and American Agriculture*. Norman: University of Oklahoma Press.

Kurlansky, Mark. 2013. *Birdseye: The Adventures of a Curious Man*. New York: Doubleday.

Lancaster, Jane. 2004. *Making Time: Lillian Moller Gilbreth—A Life Beyond “Cheaper by the Dozen.”* Hanover, NH: University Press of New England.

Latta, Susan. 2017. *Bold Women of Medicine: 21 Stories Astounding Discoveries, Daring Surgeries and Healing Breakthroughs*. Chicago: Chicago Review Press.

Manganiello, Christopher J. 2015. *Southern Water, Southern Power: How the Politics of Cheap Energy and Water Scarcity Shaped a Region*. University of North Carolina Press.

Mariani, Paul L. 2000. *The Broken Tower: The Life of Hart Crane*. New York: W. W. Norton.

Mattox, John. 2016. *Learning Analytics: Measurement Innovations to Support Employee Development*. New York: Kogan Page.

McGrayne, Sharon Bertsch. 2001. *Prometheans in the Lab: Chemistry and the Making of the Modern World*. New York: McGraw-Hill.

Midgley, Thomas. 2001. *From the Periodic Table to Production: The Life of Thomas Midgley, Jr.* Corona, CA: Stargazer.

Parissen, Steven. 2014. *The Life of the Automobile: The Complete History of the Motor Car*. New York: St. Martin's Press.

Rayner-Canham, Marelene F. 1998. *Women in Chemistry: Their Changing Roles from Alchemical Times to the Mid-Twentieth Century*. Washington, D.C.: American Chemical Society.

Schraff, Anne E. 2015. *The Life of Dr. Charles Drew: Blood Bank Innovator*. Berkeley Heights, NJ: Enslow.

Siegal, Margie. 2014. *Harley-Davidson: A History of the World's Most Famous Motorcycle (Shire Library USA)*. London: Shire.

Someda, Carlo G. 2006. *Electromagnetic Waves*. 2nd ed. Boca Raton, FL: CRC.

Sterling, Christopher H., and John Michael Kittross. 2002. *Stay Tuned: A History of American Broadcasting*. 3rd ed. Mahwah, NJ: Lawrence Erlbaum.

Strasser, Susan. 2000. *Never Done: A History of American Housework*. New York: Henry Holt.

Vassiliou, M. S. 2009. *The A to Z of the Petroleum Industry*. Lanham, MD: Scarecrow.

Wallace, Joseph. 2000. *A Gathering of Wonders*. New York: Farrar, Straus and Giroux.

Section 3: The Great Depression and World War II (1930–1945)

- Arrigo, Anthony F. 2014. *Imaging Hoover Dam: The Making of a Cultural Icon*. Reno, NV: University of Nevada Press.
- Bigelow, Stephen J. 2001. *Understanding Telephone Electronics*. Boston: Newnes.
- Byers, Nina, and Gary Williams. 2010. *Out of the Shadows: Contributions of Twentieth-Century Women to Physics*. Cambridge: Cambridge University Press.
- Chandonnet, Fern, ed. 2007. *Alaska at War, 1941–1945: The Forgotten War Remembered*. Anchorage: University of Alaska Press.
- Chiang, Tsai-Chien. 2013. *Madame Chien-Shiung Wu: The First Lady of Physics Research*. Translated by Tang-Fong Wong. London: World Scientific.
- Cimino, Al. 2016. *The Manhattan Project: the Making of the Atomic Bomb*. n.p.: Arcturus.
- Coates, Kenneth S., and William R. Morrison. 2015. *The Alaska Highway in World War II: The US Army of Occupation in Canada's Northwest*. Norman: University of Oklahoma Press.
- Dubrin, B. 2010. *Tea Culture: History, Traditions, Celebrations, Recipes & More*. Watertown, MA: Charlesbridge.
- Dunar, Andrew J., and Dennis McBride. 2001. *Building Hoover Dam: An Oral History of the Great Depression*. Reno: University of Nevada Press.
- Gordon, L. 2009. *Dorothea Lange: A Life Beyond Limits*. New York: Norton.
- Hiltzik, Michael. 2010. *Colossus: Hoover Dam and the Making of the American Century*. New York: Free Press.
- Honey, Maureen. 1999. *Bitter Fruit: African American Women in World War II*. Columbia: University of Missouri.
- Hyde, Charles K. 2014. *Painted Turtle: Images from the Arsenal of Democracy*. Detroit: Wayne State University Press.
- Kelly, Cynthia C., ed. 2010. *The Manhattan Project: The Birth of the Atomic Bomb in the Words of Its Creators, Eyewitnesses and Historians*. 2nd ed. n.p.: Tess Press/Black Dog & Leventhal.
- Kissling, Elizabeth. 2006. *Capitalizing on the Curse: The Business of Menstruation*. Boulder, CO: Lynne Rienner.
- Lederer, Susan E. 2008. *Flesh and Blood: Organ Transplantation and Blood Transfusion in 20th Century America*. Oxford: Oxford University Press.
- Lenthe, J.-V. 2011. *Flying into Yesterday: My Search for the Curtiss-Wright Aeronautical Engineering Cadettes*. El Prado, NM: Wild Hare Press.
- Macdonald, Malcolm. 2014. *The International Handbook of Space Technology*. London: Springer Praxis Books.
- Miles, Kathryn. 2017. *Quakeland: On the Road to America's Next Devastating Earthquake*. Boston: Dutton.
- Millard, André, ed. 2004. *The Electric Guitar: A History of an American Icon*. Baltimore: The Johns Hopkins University Press.
- Monk, Ray. 2014. *Robert Oppenheimer: A Life Inside the Center*. New York: Doubleday.
- Reed, W. Craig. 2010. *Red November: Inside the Secret U.S.-Soviet Submarine War*. New York: William Morrow.
- Rhodes, Richard. 2012. *The Making of the Atomic Bomb: The 25th Anniversary Edition*. New York: Simon & Schuster Paperbacks.
- Schwartz, David N. 2017. *The Last Man Who Knew Everything: The Life and Times of Enrico Fermi, the Father of the Nuclear Age*. New York: Basic Books.
- Segre, Gino, and Bettina Hoerlin. 2016. *The Pope of Physics: Enrico Fermi and the Birth of the Atomic Age*. New York: Henry Holt.
- Sluby, Patricia Carter. 2004. *The Inventive Spirit of African Americans: Patented Ingenuity*. New York: Praeger.
- Trundle, Eugene. 2001. *Newnes Guide to Television and Video Technology*. Boston: Newnes.
- Van Dijk, José. 2005. *The Transparent Body: A Cultural Analysis of Medical Imaging*. Seattle: University of Washington Press.
- Varshney, Dushyant, and Manmohan Singh. 2015. "History of Lyophilization." In *Lyophilized Biologics and Vaccines*, 3–10. New York: Springer.
- Zialoga, Steven J. 2013. *M4 (76mm) Sherman Medium Tank 1943–65*. Oxford: Osprey.

Index

Boldface numbers refer to volume numbers.

- Abbe, Cleveland (1838–1916), **2**:7–9
 Monthly Weather Review founded by, **2**:8
 National Geographic Society cofounder, **2**:8
- Abbott, John G., **1**:210–211
- Abbott Laboratories, **1**:179
- AC generator and transformer, **2**:9–10
 at Chicago World’s Columbian Exposition, **2**:58, 63, 107
 Great Barrington Electrification, **2**:9, 62
 primary document: AIEE biography for William Stanley (1934), **2**:10
 and “war of the currents,” **2**:9, 58, 62–63
- AC induction motor, **2**:10–11, 148
 primary document: Tesla’s patent (1896), **2**:11–14
- Acetylsalicylic acid. *See* Aspirin
- Acquired immune deficiency syndrome (AIDS). *See* AIDS research
- Adams, Ansel, **2**:293; **3**:80
- Adams, John, **1**:8, 10, 144, 260
- Adams, Thomas, **2**:157, 210
- Addams, Jane, **2**:172
- Adding machine with keys, **2**:14, 114
- Adding machines, **2**:14, 113–114
 Arithmometer, **2**:113–114
 automatic calculation, **1**:113–114
 clearing lever (“machine gun of the office”), **2**:114
 Comptometer, **2**:113–114
 Dalton Adding Machine (10 numerical buttons), **2**:114
 and industrialization of leisure, **2**:5
 and paper copies of tabulations, **1**:114
 See also Calculators
- Additive manufacturing. *See* 3-D printing
- Adhesive bandages, **2**:185. *See also* Band-Aid
- Adhesive tape, **1**:174–175
 Band-Aid, **1**:175; **2**:175, 185
 duct tape, **1**:175; **2**:256
 masking tape, **1**:175; **2**:113, 218, 241
 Scotch Tape (cellophane tape), **2**:113, 218, 241, 253
 as staple in American homes, **2**:253
 uses for, **1**:175
- Advanced Research Projects Agency Network. *See* ARPANET
- Aerosol spray can, **2**:176
- Aerosols
 and carbon capture and storage (CCS), **3**:40
 and chlorofluorocarbons (CFCs), **2**:176; **3**:38
 and Clean Air Act (1977), **2**:176
 definition of, **2**:176
 and Freon, **2**:205
- Agassiz, Elizabeth Cabot Cary, **1**:176, 259
 American Philosophical Society member, **1**:9
 Louis Agassiz: His Life and Correspondence, **1**:176–177
- Agassiz, Louis (1807–1873), **1**:46, 175–176
 primary document: excerpt from journal (1846), **1**:176–177
- Age of Reason. *See* Enlightenment
- Agent Orange, **3**:9–10
 discontinuation of use of, **3**:7
 naming of, **3**:9
 Operation Pacer IVY (removal of barrels from Vietnam), **3**:10
 producers of, **2**:50; **3**:9
 protests against, **3**:7
 toxicity and health effects of, **3**:9–10
- AI. *See* Artificial intelligence (AI)
- AIDS research, **3**:171–173
 AZT (zidovudine, drug treatment), **3**:172, 197
 discovery of HIV, **3**:172
 Doha declaration, **3**:172
 ELISA blood test, **3**:172
 first verified HIV case, **3**:171
 highly active antiretroviral therapy (HAART), **3**:172
 history of HIV/AIDS, **3**:171
 HIV mutations, **3**:173
 and Kaposi’s sarcoma, **3**:171, 173
 and medical technology, **3**:249
 and National Institutes of Health, **2**:105; **3**:173, 175
 and pneumocystis carinii pneumonia (PCP), **3**:171, 173
 prevention of HIV transmission, **3**:172
 primary document: introduction to AIDS archive by C. Everett Koop, **3**:173–177
 rapid HIV tests, **3**:172, 249
 and research by Salk, Jonas, **3**:126
 saquinavir (drug treatment), **3**:172

- “Air” athletic shoes, 3:11
- Airplane, 2:176–177
- airmail delivery, 2:255–256
 - contribution to decline in railroad ridership, 1:290–291
 - helicopter compared with, 2:276
 - history of, 2:176
 - and internal combustion engines, 1:120
 - and mass production, 1:75
 - first international flights (Pan American), 2:178
 - first powered, controlled aircraft (Wright brothers), 2:7, 164–166, 170–171, 178, 312
 - first transatlantic flight (Charles Lindbergh), 2:175
 - and military-industrial complex, 3:89, 90
 - NASA’s research benefits for, 3:95
 - and National Advisory Committee for Aeronautics (NACA), 2:223
 - and Pauling oxygen meter, 3:111
 - and stealth technology, 3:138–139
 - submerged airplane retrieval systems, 2:319
 - in Vietnam War, 3:9–10
 - and Whiton Centering Machine, 1:67
 - in World War I, 2:75, 171, 176, 178, 234; 3:48
 - in World War II, 2:189, 223, 234, 255–256, 261–262, 300, 301; 3:7
- See also* Drones
- Airplane deicer, 2:189; 3:254–255
- Alaska Highway, 2:257–260
- environmental effects of, 2:258–259
 - primary document: excerpt from Ruth Gruber’s study of highway routes to Alaska (1941), 2:259–260
- Alcott, Bronson, 1:168
- Alcott, Louisa May, 1:191, 306
- Alcott, William Andrus, 1:236
- Alexander, Edward Porter, 1:186
- Allen, Horatio, 1:181
- Allen, Paul, 3:199–200, 217
- Allestree, Richard, 1:11
- Almanacs. *See* Astronomical almanacs
- Almy, Brown, and Slater, 1:101, 147
- Almy, William, 1:101, 146–147
- Amalgamated Clothing Workers of America (ACWA), 2:14–16
- commitment to “new unionism,” 2:14
 - and formation of Congress of Industrial Organizations (CIO), 2:15
- See also* Labor and labor unions
- Amazon Web Services, 3:255–256, 258
- central hubs, 3:255
 - popular services, 3:255
 - users, 3:250, 255
- Amazon.com, 3:256–258
- acquisitions, 3:257, 266
 - Amazon Prime, 3:258
 - Kindle e-book reader, 3:251, 258, 265, 312
 - history of, 3:256–258
 - influence of, 3:247, 256
 - Linux’s influence on, 3:318
 - as tech start-up, 3:166, 301
 - video streaming, 3:323
- American Academy of Arts & Sciences, 1:73
- American Philosophical Society (APS), 1:8–10
- and Franklin, Benjamin, 1:4, 8–10, 45, 71–72
 - grants program, 1:9
 - and Jefferson, Thomas, 1:4, 8–9, 45, 158
 - Lewis and Clark Expedition sponsor, 1:124, 125
 - library and museum, 1:9–10
 - members, 1:8–9, 45, 46
 - and natural history movement, 1:78
 - origin and goals, 1:8, 45
 - primary document: APS’s favoring exploration of the Alaskan coast (1868), 1:10–11
 - publications program, 1:10, 97
 - sponsor of Lewis and Clark Expedition, 1:45, 124, 125
 - sponsor of Rittenhouse, David, 1:45
- American Telephone and Telegraph Company (AT&T), 2:16–17
- acquisitions of Time Warner and DirecTV, 2:17
 - AT&T Mexico, 2:17
 - Audion (triode) rights sold to, 2:196, 246
 - Bell Labs established by, 2:186, 324
 - Clarke, Edith, at, 2:268
 - court-ordered dismantling of, 2:17, 325
 - declared a monopoly by Department of Justice, 2:16, 17, 325
 - established by National Bell Telephone Company, 2:16, 27, 324
 - first long-distance lines of, 2:16
 - first undersea cable installed by, 2:16
 - Holmes Electric Protective Company purchased by, 1:183
 - innovations of, 2:16–17
 - and television technology, 2:17, 326
 - and Western Electric (subsidiary), 2:186
 - and Western Union, 1:311
 - and World War I, 2:16
 - and World War II, 2:17
- See also* Bell Telephone Laboratories
- Ames, Nathaniel, 1:11–12
- Amino acids, 3:5. *See also* DNA (deoxyribonucleic acid)
- Amphibious steam vehicle, 1:79–81
- Oruktor Amphibolos*, 1:79–81, 107, 118
 - primary document: image of amphibious steam vehicle (1834), 1:81
- Anderson, Herbert, 2:272
- Anderson, James, 1:302
- Anderson, Mary (1866–1953), 2:179
- Anderson, Paul Thomas, 3:135
- Anderson, Robert, 3:50

- Anesthesia, 1:178–179
 chloroform, 1:179, 256
 “ether frolics,” 1:178
 nitrous oxide, 1:178, 202, 203, 246–247
 sulfuric ether, 1:246–247
 types of, 1:178; 247
- Antebellum Industrialization and the Civil War (1820–1865), 1:167–174
 abolition movement, 1:171–172
 agricultural innovation, 1:171–172
 communication innovations, 1:169
 early women’s rights movement, 1:170, 172
 economic depression, 1:167, 171, 232
 education, 1:169–170
 financial panic of 1837, 1:167, 204, 217
 impact of electronic telegraph, 1:167
 industrial advancements, 1:168–169
 institutional reform, 1:167
 laissez-faire, free-market economics, 1:167, 171
 Jacksonian democracy, 1:167
 Patent Act of 1836, 1:170
 population increases, 1:167
 Second Great Awakening, 1:168, 235–236
 Transcendental Movement, 1:168, 170, 171
- Antiballistic missiles (ABMs), 3:11–12
 and Anti-Ballistic Missile Treaty (1972), 3:12, 239–240
 Strategic Defense Initiative (SDI or “Star Wars”), 3:12, 90, 239–240
- Antibiotic, 3:13–14
 antibiotic-resistant GM species, 3:271
 and cattle, 2:145
 chloramphenicol, 3:5
 development of trimethoprim, 3:196
 importance of, 3:5, 300–301, 306–307
 nystatin, 3:5, 13–14
 penicillin, 2:6, 256–257, 300–301, 306–307; 3:5, 13
 and resistant bacteria, 2:306
- Antibiotic bandages, 2:185
- Apple, 3:177–179
 Apple TV, 3:323
 competition with IBM, 3:177
 controversy and criticism, 3:178–179
 educational marketing campaign, 3:177
 Facebook App, 3:269
 Google as Safari’s default search engine, 3:253
 HyperCard, 3:190
 iCloud, 3:178, 211
 iMac, 3:178, 198
 iPad, 3:178, 180, 153, 209, 211–212
 iPhone, 3:178, 179, 180, 209, 219, 211–212, 219, 251, 269, 311–312
 iPod, 3:121, 178, 180, 209, 211–212, 251, 286, 298–299, 311
 iTunes, 3:178, 188, 209, 252, 286, 299, 308, 311
- Lisa, 3:177
- Macintosh, 3:165, 177–178, 209–210, 212, 213, 245
- Microsoft programs for, 3:200
- NeXT acquired by, 3:178
- and open-source movement, 3:221–222
- and portability, 3:253–254
- Power Macintosh (Power Mac), 3:178
- PowerBook, 3:178
- Quick Take, 2:57; 3:194
- ROKR, 3:311
- Swift coding language, 3:222
- and touch screen technology, 3:251
- and Trinity of computers, 3:223
- See also* Jobs, Steve; Wozniak, Steve
- Apple I, 3:177, 209–210, 244
- Apple II, 3:179–180
 BASIC programming language, 3:179, 244
 color monitor, 3:179, 223
 competition with Commodore, 3:179, 224
 competition with IBM, 3:205, 206
 competition with Radio Shack, 3:179
 cost, 3:180, 223
 and Dell, Michael “Saul,” 3:192–193
 mouse-central interfact, 3:159
 open architecture system, 3:42, 180
 success and importance of, 3:177, 180, 205, 209–210, 223, 244
 user-friendliness, 3:179–180, 209–210, 223
 and *VisiCalc*, 3:180, 206, 224
- Apple IIc, 3:165
- Apple III, 3:177
- Apple parers, 1:82–83
- Appleby, John, 1:304
- Apollo Project, 3:14–16
 Apollo 1, 3:15
 Apollo 8, 3:63
 Apollo 11, 3:4, 15, 63, 76, 95
 Apollo 13, 3:15
 Apollo-Soyuz Test Project, 3:4
 and Comsat/Intelsat, 3:42
 cost of, 3:14, 15
 criticism of, 3:15, 237
 and Fairchild Semiconductors, 3:131–132
 goal of, 3:14, 95
 and Hamilton, Margaret, 3:62–63
 and *Hidden Figures* (film), 3:74
 and Johnson, Katherine Goble, 3:76, 155
 largest scientific U.S. program, 3:14
 and lunar surface samples, 3:15–16
- Nike Air Tailwind, 3:11
- and Skylab, 3:133–134
- and Space Race, 3:14–15
- termination of, 3:16, 237

- Apollo Applications Program (AAP), 3:133
- Apollo telescope mount (ATM), 3: 97, 3:133
- Argenti, Felice, 1:172
- Arithmometer, 2:113–114. *See also* Adding machines
- Arkwright, Richard, 1:101, 146, 147
- Armstrong, Edwin Howard, 2:246, 272
- Armstrong, Neil, 3:4, 15, 95
- Arnold, H. H. “Hap,” 2:261, 331–332
- ARPANET, 3:16–18
- and Defense Advanced Research Projects Agency (DARPA), 3:2–3, 16, 208
 - and first e-book, 3:264
 - first email sent, 3:17
 - as forerunner to the Internet, 3:2–3, 16, 164, 190, 208, 300, 329
 - funding for, 3:16
 - and Metcalfe, Robert, 3:214
 - origins of, 3:16–17, 300
 - and packet switching, 3:17, 107
- Artificial heart, 3:180–181, 238
- Artificial intelligence (AI), 3:181–183
- AI effect, 3:183
 - approaches to, 3:181–182
 - definition of, 3:181
 - ethical concerns of, 3:183
 - future evolutions of, 3:190–191
 - and fuzzy logic systems, 3:182
 - implementation of at system level, 3:183
 - and Minsky, Marvin, 3:90–91
 - predicted by Kurzweil, Ray, 3:292
 - problems in creation of, 3:181
 - and statistics, 3:182
 - TensorFlow (Google), 3:222
- Artificial memories, 3:258–259
- Aspartame, 3:18–19
- NutraSweet (brand name), 3:18–19
 - public health concerns, 3:19
 - and saccharine, 2:137; 3:18–19
- Asphalt, 2:17–18
- invention of modern road asphalt, 2:17
 - natural asphalt (La Brea Tar Pits), 2:18
 - used for Alaska Highway, 2:258
- Aspirin, 2:18–19
- Assembly line, 2:179–181
- automated flour mill’s influence on, 1:107
 - conveyer system, 2:180
 - and crayons, 2:46
 - and Ford, Henry, 2:170, 179–180, 182, 203, 204; 3:49
 - history and invention of, 2:179
 - and interchangeable parts, 1:118, 119
 - and liberty ships, 2:294
 - moving chassis, 2:180, 182
 - myth of invention by Ford, Henry, 2:179
 - and Olds, Ransom Eli, 2:225
 - primary document: excerpt from Henry Ford’s “The First Assembly Line” (1913), 2:181
 - stationary, 2:225
 - supply chain development, 2:180
- Association for Women in Mathematics (AWM), 3:19–20
- Astor, John Jacob, IV, 2:2, 107
- Astronomical almanacs, 1:11–12
- An Almanac for New England for the Year 1639* (first American almanac), 1:11
 - Astronomical Diary and Almanack* (Ames’s *Almanack*), 1:11, 12
 - The Old Farmer’s Almanac*, 1:11
 - Pennsylvania, Delaware, Maryland and Virginia Almanack and Ephemeris*, 1:15
 - Rhode-Island Almanack*, 1:11, 15
 - Poor Richard’s Almanack*, 1:11, 12, 13, 26
 - Poor Robin’s Almanack*, 1:11
 - primary document: aphorisms from *Poor Richard’s Almanack* (1732–1758), 1:13
- AT&T. *See* American Telephone and Telegraph Company
- Atari, 3:20–22, 132
- home computers, 3:20, 22
 - Jobs, Steve, game designer at, 3:209, 244
 - lawsuit and intellectual property rights, 3:22
 - Pong*, 3:20, 21–22, 119–120, 321
 - success of, 3:20–22, 321
 - virtual reality version of, 3:323
- Atomic bombs/nuclear weapons, 2:260–261
- Fat Man and Little Boy (atomic bombs dropped on Japan), 2:261, 297
 - Hiroshima and Nagasaki attacks, 2:260–261, 272, 283, 297, 300, 303; 3:220
 - history of, 2:260
 - Trinity test (first U.S. nuclear test), 2:260, 272, 297, 303
 - See also* Manhattan Project
- Automobile technologies (pre–World War II), 2:181–183
- assembly line, 2:179–181, 182, 203, 204
 - “Big Three” U.S. automobile makers, 2:183
 - closed-body cars, 2:182
 - company competition, 2:182
 - fenders, 2:181, 183
 - Great Depression’s effect on, 2:182
 - hydraulic brakes, 2:181, 182
 - reinforced glass, 2:182–183
 - transitional phase, 2:181
 - V8 engine, 2:181, 182
 - Vintage Era, 2:181–183
 - Y Job fender, 2:183
- Automotive technologies (post–World War II), 3:22–24
- automatic transmissions, 3:23
 - battery and energy storage technologies, 3:23
 - “Big Three” U.S. automobile makers, 3:22
 - and dynamic obsolescence, 3:22
 - electric vehicles (EVs), 3:23, 49–53, 247, 281

- electronic and computer systems, 3:23
- and Federal-Aid Highway Act (1956), 3:23
- and government regulations, 3:23
- hybrid-electric vehicles (HEVs), 3:23, 49–53, 247, 281–283
- independent suspensions, 3:23
- and post-war consumer demand, 3:22
- safety technologies, 3:23
- V8 engine, 3:22–23
- Avenger Field, 2:261–263
 - home of Women Airforce Service Pilots (WASPs) of World War II, 2:261–262
 - primary document: letters of Mary Anna Martin Wyall, WASP pilot trainee (1944), 2:262–263
- Ayers, Robert, 1:95–96, 173
- B-17 Flying Fortress, 2:263–264
- Babbitt, Isaac, 1:179–180
- Babbitt, Sarah “Tabitha” (1779–1853), 1:84, 97
- Babbitt metal, 1:179–180
- Bacon, Roger, 1:11
- Bakeland, Leo Hendrik, 2:183–184
- Baer, Ralph (1922–2014), 3:24–25
 - Brown Box (first home video console), 3:24
 - as “Father of Video Game,” 3:24
 - primary document: excerpt from paper describing plans for simple video games (1966), 3:25
- Bailey, Robert, 1:11
- Baird v. Eisenstadt*, 3:32
- Bakelite, 2:183–185
- Ball bearings and Babbitt metal, 1:179–180
- Ballard, Martha (1735–1812), 1:75, 84–85
 - on currency, 1:85–86
 - diary of, 1:85
 - and *A Midwife’s Tale* (based on Ballard’s diaries), 1:86
 - on midwifery, 1:85
 - primary document: diary excerpts describing home weaving, 1:39–40
 - on textile work, 1:39–40, 86
 - on violence against women, 1:86
- Baltimore and Ohio (B&O) Railroad, 1:310
 - competition with Chesapeake and Ohio Canal, 1:94
 - oldest U.S. railroad, 1:7, 275, 289
 - Tom Thumb* (first U.S. steam engine) created for, 1:7; 2:150, 153
- Band-Aid, 1:175; 2:175, 185
- Banjo clock, 1:87
- Banneker, Benjamin (1731–1806), 1:13–15
 - almanacs of, 1:11, 12, 13–14, 15, 177
 - primary document: letter from Thomas Jefferson expressing that blacks had talents equal to other races (1791), 1:14–15
 - primary document: frontispiece of *Pennsylvania, Delaware, Maryland and Virginia Almanack and Ephemeris* (1792), 1:15
- solar eclipses studied by, 1:13, 77
- Bar code scanner, 3:25–27
 - RFID tag as alternative to, 3:306, 307
- Baran, Paul, 3:17, 107
- Barbed wire, 2:4, 19–23, 196
 - controversial wartime use of, 2:20
 - and history of wire, 1:19
 - invention of, 2:19
 - primary document: article excerpt on Joseph F. Glidden and the barb-wire industry (1884), 2:21–23
- Bardeen, John, 3:1, 131, 140, 148
- Barnum, P. T., 1:10, 184; 2:30–31
- Barton, Clara, 1:84–85
 - Civil War nurse, 1:191
 - primary document: “The Women Who Went to the Field” (1892), 1:192–193
 - Red Cross founded by, 1:264, 306
- Bashen, Janet (1957–), 3:259
- Batteries, 2:23
 - in artificial hearts, 3:181
 - and Edison, Thomas, 2:59
 - in electric and hybrid-electric vehicles, 2:23; 3:23, 49–53, 247, 282
 - in electric doorbells, 1:123
 - and electromagnets, 1:199
 - and environmental concerns, 2:23
 - in portable electronics, 3:165, 166, 251, 286
 - rechargeable, 2:23, 38
 - in smoke detectors, 3:136
 - in transistor radios, 3:148
 - in urban electrification, 2:63
- Bayer, Friedrich, 2:18–19
- Bayer & Company, 2:18–19
- Bee smoker, 2:24–25
 - primary document: excerpt from Moses Quinby’s *Mysteries of Bee-Keeping Explained* (1853), 2:24–25
- Beecher, Catherine, 1:170
- Bell, Alexander Graham (1847–1922), 2:26–28
 - biographical details, 2:26
 - credited with first practical telephone, 2:5, 26–27, 322–325; 3:329
 - and invention of the phonograph, 2:117, 209
 - metal detector invented by, 2:97–98
 - primary document: letter to parents describing idea for the telephone (1874), 2: 27–28
- Bell, Patrick, 1:205
- Bell Telephone Laboratories (Bell Labs), 2:16, 185–186, 324
 - Advanced Mobile Phone System (AMPS) developed by, 3:218
 - Multiplexed Information and Computing Service (MULTICS), 3:314
 - transistor created at, 2:17, 324; 3:131
 - vocoder created at, 3:155

- Bellanca, Dorothy Jacobs, 2:15
- Benedictus, Edouard, 2:183
- Benerito, Ruth Rogan (1916–2013), 3:27
 permanent press fabric invented by, 3:27, 111–112
 wash-and-wear cotton fabrics developed by, 3:27
- Benham, Rhoda W., 3:13
- Benz, Karl, 2:181
- Berlin Wall, fall of, 3:164
- Berliner, Emile (1851–1929), 2:29–30
- Berners-Lee, Tim (1955–), 3:184–185
 at CERN, 3:165, 184, 208
 and creation of World Wide Web, 3:163, 165–166, 184–185
 HTML developed by, 3:165, 184, 208, 300
 HTTP developed by, 3:165, 208, 184
 URL developed by, 3:184, 208
 World Wide Web Consortium (W3C) founded by, 3:184, 209
- Berry, George Stockton, 1:205
- Bessemer, Henry, 2:1, 34–36, 89–90, 139–140, 160, 201
- Bessemer steel, 2:35–36, 89, 139–140
- Best Friend* steam engine, 1:181
- Bifocals, 1:16–17
 bifocal and progressive contact lenses, 1:17
 invention of, 1:4, 16, 26
 primary document: Benjamin Franklin's letter describing his invention of bifocals (1725), 1:17
- Big science, 2:264–265
- Bilas (Spence), Frances, 3:1, 56
- Binney, Edwin, 2:45–46, 186–187
- Binney, Joseph, 2:46, 186
- Binney & Smith Inc., 2:46, 186–187
- Biodiesel, 3:27–38
 primary document: statement of Anne Steckel to Senate committee (2016), 3:29–31
- Birdseye, Clarence (1886–1956), 2:187–188
- Bishop, John Michael, 3:261
- Bissell, George, 2:90
- Bissell, Melville Reuben, 2:38
- Blacksmithing. *See* Iron- and silversmithing
- Blackwell, Elizabeth (1821–1910), 1:87–91
 primary document: excerpts from “Address on the Medical Education of Women” (1863), 1:89–91
- Blackwell, Emily, 1:88–91
- Blanchard, Thomas, 1:74–75, 244
- Blender, 2:188
- Blizzard Entertainment, 3:260
- Blodgett, Katherine (1898–1979), 2:188–189
- Blood transfusion, 2:173, 199, 265–266; 3:172
- Boeing, William E. (1881–1956), 2:189–190
- Boeing Company, 2:178, 189–190; 3:232, 237, 302
- Boggs, David, 3:215
- Boggs, Hale, 2:288
- Bohr, Niels, 3:80, 305
- Bomb disposal robots/units, 3:33
- Bomford, George, 1:204–205
- Borden, Gail, III, 1:173
- Boston Associates, 1:147, 161
- Boston Tunnel, 3:185–186
- Bottle-making machine, 2:190–191
- Bowditch, Nathaniel, 1:75–76, 77, 137
- Bradberry, Henrietta (1903–1979), 2:266–267
- Brandeis Brief (*Muller v. Oregon*), 2:104, 172
- Brattain, Walter, 3:1, 131, 148
- Bread slicer and wrapping machine, 2:191
- Breast pump, 1:182
- Brill, Yvonne Madalaine Claeys (1924–2013), 3:34–35
 primary document: patent for new jet propulsion technology (1974), 3:35
- Brooklyn Bridge, 2:30–31
 construction of, 2:30
 as National Historic Landmark, 2:31, 132
 primary document: photograph of promenade on Brooklyn Bridge, 2:131
 renovation (2010–2015), 2:31
- Brown, Harold Pitney, 2:62
- Brown, Josiah, Jr., 1:182–183
- Brown, Louise, 3:70
- Brown, Marie Van Brittan (1922–1999), 3:35
- Brown, Moses, 1:146–147
- Brown, Rachel Fuller, 3:5, 13–14
- Brown, William, 1:282
- Brown Box (first home video console), 3:24
- Brown Ferry Plant (nuclear plant), 2:329
- Brown Truss, 1:182–183
- Brown v. Board of Education*, 2:52
- Brownie (Kodak camera), 2:33, 57, 120, 133, 171
- Browning, John M. (1855–1926), 1:248–249
- Brownson, Orestes, 1:168, 171
- Bryant, Alice (1862–1942), 2:192
- Buchner, Joseph, 2:18
- Bulletproof vest/Kevlar, 3:36, 77
- Bullock, William, 1:174, 271
- Burglar alarm, 1:183
- Burks, Arthur, 3:55
- Burr, Theodore, 1:91–92
- Burr truss bridge, 1:91–92
- Burroughs, William S., 2:14, 114
- Burt, William Austin, 1:168, 225–226, 287
- Bush, George H. W., 3:197
- Bush, George W., 3:12, 72, 90, 239, 240, 319
- Bushnell, David (1740–c. 1824), 1:17
 primary document: engraving of American *Turtle* (1775), 1:18
 primary document: letter to Thomas Jefferson regarding experiments, 1:66–67

- Turtle* submarine created by, 1:17–18, 65, 301
 Bushnell, Nolan, 3:20–22, 119–120
- Calculators**
 Clarke Calculator (graphing calculator), 2:268
 digital logarithmic converter, 3:326
 electromechanical calculator, 3:69
 handheld calculators, 3:68, 77, 326
 and history of personal computers, 3:223–224
 microprocessors used in, 3:133
 mobile phones as, 3:219
 photovoltaic cells used in, 3:235
See also Adding machines
- Calliope (steam organ), 1:183–185
- Calutron Girls, 2:267–268
- Camera, 2:31–33
 Brownie (Kodak), 2:33, 57, 120, 133, 171
 daguerreotype, 2:31–32, 120
 digital photography, 3:167, 193–195
 first recorded movie, 2:33
 history of, 3:31–33
 in home security systems, 3:35
 photographic film, 2:120–121
 photography of Civil War, 1:256
 pinhole cameras, 2:31
 Polaroids, 3:79–80, 117–118
 in space probes, 3:75, 156, 297
 in stealth aircraft, 3:140
 in virtual reality technology, 3:324, 325
- Can opener, 3:33–34
- Canals, 1:92–95
 American canal systems, 1:6, 94
 Bridgewater Canal, 1:93
 Chesapeake and Ohio Canal, 1:94
 early canal building, 1:6
 and lamp oil discovery, 2:90
 and Industrial Revolution, 1:93
 Middlesex Canal, 1:6, 93
 oldest known American canal, 1:93
 purpose of, 1:92–93
See also Erie Canal; Panama Canal
- Cancer research, 3:261–252
 American Cancer Society (ACS), 3:262
 Cancer Genome Atlas (TCGA), 3:262
 contributions of American organizations, 3:261
 discoveries by American scientists, 3:261
 and National Cancer Act (1971), 3:261
 National Cancer Institute, 3:261–262
 Philadelphia chromosome, 3:262
- Canning factory, 1:95–96
- Cannon, Annie Jump (1863–1941), 2:192–193
- Cannon, double-barrel, 1:185–186
 primary document: excerpt from memoirs of Edward Porter Alexander on “artillery hell” at Antietam (1907), 1:186
- Carbutt, John, 2:43
- Carey (Agassiz), Elizabeth Cabot, 1:176
- Carey, Henry Charles, 1:167, 171–172
- Carnegie, Andrew (1836–1919), 2:34–35
 biographical details, 2:34, 35–36
 Carnegie Steel Company founded by, 2:34–35
 and Gilded Age “robber barons,” 2:34
 and U.S. Steel, 2:34
- Carnegie Steel Mill, 2:1, 35–37
 and competitive advantage, 2:36–37
 and cost control, 2:36
 and Panic of 1873, 2:35, 36
 primary document: correspondence of Andrew Carnegie and Henry Clay Frick regarding the Homestead Strike (1892), 2:35, 37
 purchased by Morgan, J. P., 2:35, 36–37
 and vertical integration, 2:34–36
- Carothers, Wallace (1896–1937), 2:194; 3:7
- Carpet sweeper, 2:38
- Carson, Rachel (1907–1964), 3:36–38
The Edge of the Sea, 3:37
 and public suspicion of chemical products, 3:18
The Sea Around Us, 3:6, 37
Silent Spring, 2:288–289; 3:6–7, 18, 36–38, 129–130
- Carter, Jimmy, 2:105, 228; 3:104, 113, 129, 139, 272
- Carver, George Washington (1861–1943), 2:38–39
 crop rotation innovations by, 2:39–40
 and peanut products, 2:39
 primary document: George Washington Carver addresses Congress (1921), 2:41–42
- Cash register, 2:42
- Cassini Saturn Mission, 3:127, 262–263
 discoveries of, 3:262–263
 and Jet Propulsion Laboratory (JPL), 3:75
 purpose of, 3:262
- Cayley, George, 2:165, 176
- CD and DVD, 3:186–188
- CD-ROM, 3:188–189
- Cellophane, 2:53
- Cellophane tape, 2:113, 218, 241, 253
- Celluloid, 2:42–43
- Centers for Disease Control and Prevention (CDC)
 AIDS research, 3:171, 173–174
 Jemison, Mae, at, 3:290
 polio vaccine recommendations, 3:118
- CERN (Conseil Européen pour la Recherche Nucléaire, or European Council for Nuclear Research), 3:108, 165, 184, 208
 primary document: press release, 3:109–110
- Channing, William Francis, 1:227–228
- Charpentier, Jean de, 1:176
- Charting the Gulf Stream, 1:96–97
- Child labor, 1:162, 298; 2:2, 7, 104–105
- Chlorofluorocarbons (CFCs), 3:38–39

- and aerosol spray cans, 2:176
- and Freon, 2:204–205, 220, 311; 3:38, 192
- invention of, 2:219–220; 3:38
- Christian, Charlie, 2:270–271
- Christmas tree lights, 2:194–195
- Chu, Jeffrey Chuan, 3:55
- Chuck wagon, 2:195–196
- Circular saw, 1:97–98
- Civil War medicine (1861–1865), 1:186–190
 - amputations, 1:188
 - hospitals, 1:187–188
 - long-term care, 1:188
 - primary document: report on Union casualties suffered at the Battle of Shiloh (1862), 1:188–190
 - and United States Sanitary Commission (USSC), 1:187, 306–307
 - wartime deaths, 2:186–187
 - wound treatment and surgery, 1:187–188
- Civil War nursing, 1:190–193
 - and Catholic sisters, 1:191
 - primary document: Clara Barton's poem "The Women Who Went to the Field" (1892), 1:192–193
 - race and class structure of, 1:191
- Civilian Pilot Training Program (CPTP), 2:261
- Clark, Barney, 3:180
- Clark, James H., 3:301
- Clark, William, 1:8, 123–127. *See also* Lewis and Clark Expedition
- Clarke, Edith (1883–1959), 2:268
- Clarke, William Edward, 1:178
- Clarke calculator, 2:268
- Clarke School for the Deaf, 2:26
- Climate change, 3:39–41
 - and carbon capture and storage (CCS), 3:40
 - causes of, 3:39
 - and dams, 2:213
 - disagreements and controversy, 3:39
 - and Freon, 2:311
 - and *An Inconvenient Truth* (documentary), 3:39
 - and Kyoto Treaty, 3:40
 - and Paris Agreement, 3:41
 - and solar radiation management, 3:40
 - and urban electrification, 2:65
- Clinton, Bill, 3:227
 - and International Space Station, 3:284
 - and Kyoto Treaty, 3:40
 - military reduced by, 3:90
- Clinton, Hillary, 3:323
- Clipper ship, 1:194–196
 - Baltimore clippers, 1:194
 - packet ships, 1:194
 - primary document: journal excerpts of Alexander Van Valen describing journey to California via clipper ship (1849), 1:196
 - Rainbow* (considered first true clipper), 1:194
- Clothespin, 1:196–197
- CO₂ welding, 3:41
- Coal-mining technologies, 1:197–198
 - and damp (gas pockets), 1:198
 - early coal mining, 1:198
 - and labor unions, 1:198
 - safety of, 1:198
 - stripmining, 1:197
 - surface mining, 1:197
 - underground mining, 1:197–198
- Coca-Cola, 2:43–44
- Cochran, Jacqueline, 2:263, 331–332
 - and formation of Women's Airforce Service Pilots (WASPs), 2:331–332
 - Women's Flying Training Detachment (WFTD) director, 2:261, 332
- Cochran, Josephine, 2:4, 48–49
- Coffee percolator, 1:98–99
- Coil magnet/electromagnet, 1:199
- Cold War (1946–1979), 3:1–8
 - advances in biological science and medicine, 3:4
 - dawn of computer science, 3:1
 - definition of, 3:1
 - environmental activism, 3:6–7
 - global communications and Internet, 3:2–3
 - nuclear arms and nuclear power, 3:5–6
 - rapid technological change, 3:1
 - Space Race, 3:3–4
 - widespread use of synthetic materials, 3:7
- Colden, Jane (1724–1766), 1:19–20, 45
- Colgate, William (1783–1857), 1:200
- Collier, Ralph, 1:222
- Colton, Gardner Quincy, 1:178
- Colonial America and Enlightenment society, 1:1–8
 - as "Age of Reason," 1:1
 - cotton industry, 1:5–6
 - economics of colonial settlements, 1:2–3
 - and England's Iron Act (1750), 1:3
 - harnessing electricity, 1:1
 - indigenous people's experience, 1:2
 - and Industrial Revolution, 1:4–5
 - Jamestown colony, 1:2, 38
 - and mercantile system, 1:3, 5, 60–61, 138
 - putting-out production replaced by factory system, 1:4, 5
 - study of natural sciences, 1:3–4
 - transportation advances, 1:1
- Colored Female Free Produce Society, 1:201–202
- Colt, Samuel (1814–1862), 1:202–203
 - Colt Patent Fire-Arms Manufacturing Company, 1:202
- Colt revolver, 1:203–204
- Columbiad Cannon, 1:204–205
- Colvin, Margaret, 2:4, 134
- Combine harvester, 1:205–207

- Commodore 64, 3:42, 224
- Compact iron stove, 1:207–208
- Comptometer, 2:113–114. *See also* Adding machines
- Computer/information technology, 3:189–191. *See also*
 Apple; Apple II; Commodore 64; IBM personal computer; Personal computer
- Comsat/Intelsat, 3:42–43
 and Communications Satellite Act (1962), 3:2, 42
 creation of COMSAT Corporation, 3:2
 Intelsat I (first operational satellite), 3:42
- Comstock Law (1873), 3:32
- Conestoga wagon, 1:208–211
 primary document: excerpt from John G. Abbott's
 recollections of traveling to California by wagon train
 (1852), 1:210–211
- Constitution. *See* United States Constitution
- Constitutional Convention (1776), 1:53
- Constitutional Convention (1787), 1:26, 112, 136
- Cook, Tim, 3:179
- Coolidge, Calvin, 2:174, 237
- Coolidge, William D., 2:199–200
- Cooper, Gordon, 3:88
- Cooper, Leon Neil, 3:140–141
- Cooper, Martin, 3:218
- Cooper, Peter
 first steam-powered locomotive (*Tom Thumb*) created by,
 1:7, 150, 289; 2:150
 grandfather to Hewitt, Peter C., 2:210
 primary document: John Latrobe's description of *Tom
 Thumb*, 2:150–152
 wrought iron beams pioneered by, 2:139
- Cooper pairs, 3:141
- Corn sheller, 1:211
- Corps of Discovery. *See* Lewis and Clark Expedition
- Corset, 1:211–213
- Coston, Martha (1826–1904), 1:213
- Cotton candy machine, 2:45
- Cotton gin, 1:99–101, 119
 and demand for cotton, 1:101
 Greene, Catharine Littlefield, as coinventor of, 1:5, 116,
 117, 164–165
 influence and legacy of, 1:5, 74, 82, 86, 99–100
 invention of, 1:5, 99, 164–165
 and spinning wheel, 1:60, 61
 and Waltham-Lowell textile system, 1:161
- Cotton sewing thread, 1:101
- Cowboy hat (Stetson), 1:213–214
- Crane, Clarence, 2:217
- Cray, Seymour (1925–1996), 3:191–192
- Crayons, 2:45–46
- Crick, Francis, 3:5, 202
- Crocker, Charles, 1:275, 290
- Crosby, Caresse. *See* Jacob, Mary Phelps
- Crosley Motors, 2:182
- Crump, Scott, 3:316
- Crumpler, Rebecca (1831–1895), 1:214–215
- Crystal Palace Exhibition. *See* Great Exhibition of 1851
 (London)
- Curanderas*, 3:43–45
- Curling iron, 2:47
- Curtiss-Wright Aeronautical Engineering Cadettes,
 2:269–270
- Cuvier, Georges, 1:176
- Cylinder pin tumbler lock, 1:216
- Czarnecki, Kazimierz, 3:73
- D rations, 2:270, 300
- da Vinci, Leonardo, 2:143
 and flying machines, 2:176, 177
 gas engine prototype, 2:247
 and pedometer, 1:122
 pinhole camera used by, 2:31
 and underwater sound waves, 2:318
- da Vinci Surgical System, 3:229, 230–232, 250
- Dabney, Ted, 3:20–22, 119–120
- Daguerre, Louis, 2:31–32, 130
- Dahlgren gun, 1:216–217
- Dark matter science, 3:45–47
- Darken, Joanne, 3:19
- Dart, Joseph, 1:233–234
- Darwin, Charles
 American Philosophical Society member, 1:9
 evolution theory opposed by Agassiz, Louis,
 1:175, 176
 Gosling, James, on Darwinism, computers, and human
 evolution, 3:289
 and Haeckel, Ernst, 2:129
 Hawking, Stephen, compared to, 3:277
 Rush, Benjamin, on, 1:145
 on “selective breeding,” 3:202
- Davidson, Arthur, 2:221–222
- Davis, Donald, 3:107
- Davis, Jack, 3:35
- Davis, Jan, 3:291
- Davy, Humphry
 arc lamp of, 1:198
 nitrous oxide experiments of, 1:246, 247
 and short electric arc, 1:116, 198
- Daylight Saving Time, 1:20
- DDT (dichlorodiphenyltrichloroethane), 2:301; 3:6, 18, 36,
 38, 130
- de Forest, Lee (1873–1961), 2:196–197
- de la Peña, Carolyn, 2:136; 3:19
- de Smedt, Edward J., 2:17–18
- Deductive reasoning, 1:1, 3, 7
- Deere, John (1804–1886) and Deere and Company, 1:159,
 205, 217–220
 polished steel plow invented by, 1:171, 217–218, 269

- Defense Advanced Research Projects Agency (DARPA), 3:2–3, 16, 208. *See also* ARPANET
- Dell, Michael “Saul” (1965–), 3:192–193
- Demikhov, Vladimir, 3:180
- Demorest, Ellen Curtis, 1:286
- Denison, Lester E., 1:211
- Denny, James, 3:19
- Denny, Reginald, 3:48
- Dental chair, 1:219
- Dental floss, 1:102–103
- Detachable collar, 1:219–220
- Dexter, Henrietta F., 3:13
- Dickelman, Elizabeth (dates unknown), 2:197
- Dickerson, Mary Cynthia (1866–1923), 2:197–198
- Diesel, Rudoph, 3:28
- Diffraction grating, 1:103
- Digital photography, 3:193–195
primary document: excerpt from patent for Kodak’s digital camera (1978), 3:195
- Diner (horse-drawn), 2:47–48
- Dishwashing machine, 2:48–49
- Dix, Dorothea (1802–1887), 1:220–221, 308
activist for mentally ill, 1:220–221
Civil War superintendent of army nurses, 1:187, 191, 221, 264
and U.S. Sanitary Commission (USSC), 1:306
- DNA (deoxyribonucleic acid), 3:4–5, 93, 109, 153, 196
gene patenting, 3:270–271
genetic engineering, 3:201–205
genetically modified foods, 3:271–273
Human Genome Project, 3:279–280
- Dolby Laboratories, 3:47
- Dow Chemical Company, 2:49–50
- Drake equation, 3:264
- Dred Scott v. Sandford*, 1:172
- Drew, Charles (1904–1950), 2:198–199
- Drones, 3:48–49
and Amazon package delivery, 3:258
and artificial intelligence, 3:183
drone warfare, 2:301–302; 3:48
electroexpulsive technology used in, 3:255
history of, 3:48
“Lightning Bugs,” 3:49
as natural progression of helicopter technology, 2:277
Predator missiles, 3:48
Quail decoy drone, 3:140
and stealth technology, 3:140
in World War I, 3:48
World War II German drones, 2:301–302
- Du Mont, Allen B., 1:78
- du Pont, Éleuthère Irénée, 1:77
- du Pont, Pierre (1870–1954), 2:50–52
- Duct tape, 1:175; 2:256. *See also* Adhesive tape
- Ductile tungsten, 2:199–200
- Dudley, Benjamin, 1:246–247
- Dudley, Homer, 3:155
- DuPont Company, 1:77; 2:52–54
- Duprey, Ana Roqué de (1853–1933), 2:54
- Duryea, Charles (1861–1938) and Frank (1869–1967), 2:54–55
- Dust Bowl
and Lend-Lease Program, 2:294
photographs by Lange, Dorothea, of, 2:292–293
overfarming as cause of, 1:207
- Dustpan, 1:221–222
- Earth Resources Technology Satellite (ERTS-1), 3:2
- Ebers Papyrus (Egyptian medical scroll of herbal knowledge), 2:18
- e-book and e-reader, 3:264–266
Kindle, 3:251, 258, 265, 312
- e-Sports, 3:267–268
- Earl, Harley, 2:183
- Earmuffs, 2:55
- Eastman, George (1854–1932), 2:56
- Eastman Kodak Company, 2:56–57
- Eckert, John Presper, 3:55, 150–151
- Eckert-Mauchly Computer Corporation, 3:65, 69
- Edison, Thomas (1847–1931), 2:5, 40, 43, 57–59, 143, 194–195, 324
biographical details, 2:57–58
direct current system, 2:107, 147–148
and Ford, Henry, 2:59, 203
Kinematoscope, 2:6, 91, 103
lightbulb patented by, 2:47, 58
and motion pictures, 2:243–244
phonograph invented by, 2:115–118, 208–210
quadruplex telegraph invented by, 2:26, 124–125
- Edison effect, 2:196
- Edison Electric Light Company, 2:5, 61, 194
- Edison General Electric Company, 2:74
- Edwards, Robert, 3:70
- Eggbeater, 1:222
- Eichengrün, Arthur, 2:19
- Einstein, Albert (1879–1955), 2:199–201, 224, 260, 271–272, 304, 317
biographical details, 2:199–200
on dangers of nuclear weapons, 3:201, 111
photoelectric effect defined by, 3:235
and quantum science, 3:304–305
stimulated emissions theory proposed by, 3:80
- Eisenhower, Dwight D.
Atoms for Peace program, 3:6, 128
election of 1952, 3:151
and Federal-Aid Highway Act (1956), 3:23
and military-industrial complex, 3:88–90
NASA established by, 3:3, 94, 137

- and oil quotas, 3:112
- primary document: letter to Glennan, Keith, retiring administrator of NASA, 3:98
- and Shippingport Atomic Power Station, 3:128–129
- Electric car, 3:49–53, 247, 281
 - primary document: article from the energy.gov web site (2014), 3:50–53
- Electric doorbell, 1:223–224
- Electric guitar, 2:270–271
- Electric iron, 2:59–60
- Electric lightbulb, 2:60–61
- Electric stove, 1:223
- Electric street railway, 1:223–224
- Electrical tape, 1:175. *See also* Adhesive tape
- Electricity, war of the currents, 2:61–63
- Electrification, urban, 2:63–65
- Electroexpulsive technology, 3:254–255
- Electromagnetic induction, 1:7, 168, 237; 2:10–11, 323. *See also* AC induction motor
- Electronic Numerical Integrator and Computer. *See* ENIAC and the “ENIAC Girls”
- Elevator safety brake, 1:224–225
- Elion, Gertrude (1918–1999), 3:195–197
- Emerson, Ralph Waldo, 1:168, 171
- Empire State Building, 2:201–202
- Enders, John Franklin (1897–1985), 3:4, 54
- Engelbart, Douglas (1925–2013), 3:3, 55
- ENIAC and the “ENIAC Girls,” 3:1, 55–56
 - designers, 3:55, 151
 - first electronic general-purpose computer, 3:55
 - programmers (ENIAC Girls), 3:56
 - purpose of, 3:55, 189
- Enlightenment
 - and consequences of change, 1:7–8
 - and deductive reasoning, 1:1, 3, 7
 - impact of, 1:1
 - and inoculation, 3:151–152
 - population redistribution, 1:8
 - Tesla, Nikola, on Niagara Falls Power Plant as testament to, 2:110
- See also* Colonial America and Enlightenment society
- Equatorial sextant, 1:168, 225–226, 287
- Erie Canal, 1:104–107, 245
 - construction of, 1:6, 105
 - importance and legacy of, 1:6, 76, 78, 83, 94, 105, 233
 - primary document: letter of Robert Fulton to George Washington urging construction of canals (1797), 1:106–107
 - and steam railroad construction, 1:7, 105, 293
- Escalator, 2:65–67
- Ethernet, 3:132, 190, 214–215
- Evans, Oliver (1755–1819), 1:79–81, 107–109
 - biographical details, 1:79, 107
- first amphibious steam vehicle (*Oruktor Amphibolos*) built by, 1:79–80, 107, 118
- high-pressure steam engine developed by, 1:117–118
- ice-making machine designed by, 1:161, 268
- influence of, 1:73–74, 76–77, 107–108, 117–118
- and patent conflict with Jefferson, Thomas, 1:108–109, 136
- Mars Iron Works founded by, 1:118
- primary document: image of amphibious steam vehicle (1834), 1:81
- primary document: letters to Thomas Jefferson (1804, 1808), 1:108–109
- steam-powered flour mill invented by, 1:73–74, 107, 107–108, 234
- The Young Millwright and Miller’s Guide*, 1:73, 107
- Explorer (browser). *See* Internet Explorer
- Explorer I, 3:3, 74, 92, 93, 95, 121
- Extension arm (long arm), 1:21
- Extinction, species, 1:47, 175, 176; 3:250
- Facebook, 3:268–270
- Fahlberg, Constantin, 2:135–136; 3:18
- Fairbanks, Erastus, 1:168; 2:268–269
- Fairbanks, Thaddeus, 1:168, 268–269, 291
- Falconer, Etta, 3:20
- Faraday, Michael, 1:7, 168, 237; 2:10, 323
- Farber, Sidney, 3:261
- Federal-Aid Highway Act (1956), 2:287–290
 - primary document: excerpt from the Federal-Aid Highway Act (1956), 2:289–290
- Fender, Leo, 2:271
- Fermi, Enrico (1901–1954), 2:260, 271–272, 283, 296, 331
- Ferraris, Galileo, 2:10
- Ferris wheel, 2:66–68
 - primary document: telegrams between Luther Rice and George Ferris on successful test of the Ferris wheel (1893), 2:68
- Feynman, Richard P., 2:260, 317; 3:93
- Field, Cyrus West (1819–1892), 1:226–227; 2:5
- Finely, Susan, 3:121
- Fire alarm call box, 1:227–228
- Fire hydrant, 1:109–111
 - primary document: account of the Detroit Fire (1805), 1:110–111
- Fire Safety, 1:21–22
- Fitch, John (1743–1798), 1:76, 111–112
 - biographical details, 1:111
 - first successful steam-powered boat developed by, 1:111–112, 115, 151
 - monopoly granted to, 1:111–112, 136, 293
- Fitzroy, Nancy DeLoye, 1:78
- Flatboat, 1:112–114
- Flexible catheter, 1:22–23

- Floating dry dock (1849), 1:228–230
 primary document: excerpt from Abraham Lincoln's patent application for the floating dry dock (1849), 1:229–230
- Floppy disk, 3:197–198
- FM radio, 2:272–273
- Folding cabinet bed, 2:68–70
 primary document: patent for folding cabinet bed (1885), 2:69–70
- Folger, Timothy, 1:96–97
- Folsom, Joseph Libbey, 1:172
- Food and Drug Administration (FDA), 3:172
 and AIDS research, 3:172, 239
 and artificial sweeteners, 2:137; 3:18–19
 and birth control, 3:32, 307
 on cosmetic surgery, 3:249
 creation of, 2:172
 first female lab chief, 2:232
 and genetically modified foods, 3:272
 primary document: letter on regulation of robotic surgery (2013), 3:230–232
 and robotic surgery, 3:229, 230, 250
 and toothpaste categorization, 1:300
- Food preservation, 2:70–71
- Food production, Native American, 1:23–25
- Ford, Henry (1863–1947), 2:36, 40, 202–204
 and assembly line, 2:170, 179–181
 biographical details, 2:202–203
 and Edison, Thomas, 2:59, 203
 “Fordism,” 2:204
 Model A, 2:181, 203–204
 Model T, 2:170, 180, 182, 203–204
- Fortran, 3:56–57, 69, 121, 155
- Fossey, Dian (1932–1985), 3:198–199
- Fountain pen, 2:71–72
- Franklin, Benjamin (1706–1790), 1:4, 25–27
 American Philosophical Society created by, 1:4, 71–72
 electricity experiments, 1:4
 glass armonica invented by, 1:4, 31, 32
 primary document: letter describing experiments with electricity (c. 1750), 1:26–27
- Franklin, James, 1:11, 25
- Franklin stove, 1:27–31
 primary document: Excerpt from *An Account of the New Invented Pennsylvanian Fire-Places* (1744), 1:28–31
- Frasch process, 2:72–72
- Freeze-dried food, 2:273
- Freireich, Emil Jay, 3:261
- French and Indian War (1754–1763), 1:3, 35, 208
- Freon, 2:204–205, 215, 220, 311; 3:38, 192
- Frick, Henry Clay, 2:35
 primary document: correspondence with Andrew Carnegie regarding Homestead Strike (1892), 2:37
- Fugitive Slave Act (“Compromise of 1850”), 1:172
- Fuller, Richard Buckminster (1895–1983), 3:57–58
 primary document: drawing of R. Buckminster Fuller's Geodesic Dome (c. 1933), 3:58
- Fulton, Robert (1765–1815), 1:114–115
- Gaffer tape, 1:175. *See also* Adhesive tape
- Gagarin, Yuri, 3:4, 237
- Gallo, Robert, 3:172, 175
- Galvin, Joseph, 2:205
- Galvin, Paul Vincent (1895–1959), 2:205–206
 biographical details, 2:205
 mass production process of automotive radios created by, 2:205–206
 Motorola cofounded by, 2:182
 and Motorola 5T71 radio, 2:205–206
- Garbage disposal, 2:273–274
- Gas mask, 2:274
- Gas transmission, 2:73–74
- Gas tungsten arc welding, 1:115–116
- Gas well, 1:230
- Gates, Bill (1955–), 3:163, 199–201, 244
 on artificial intelligence, 3:183, 191
 Bill & Melinda Gates Foundation, 3:212, 199, 201, 270
 cofounder of Microsoft, 3:190, 199–201, 217, 218
 and Jobs, Steve, 3:211, 212
- Gatling, Richard, 1:174, 247–248
- Gene patenting, 3:270–271
- General Electric, 2:74–75
- General Motors (GM), 2:206–207
- Genetic engineering, 3:201–204
- Genetically modified foods, 3:271–273
- Geographic Information Systems (GIS), 3:164
- Gibbs, Mifflin Wistar, 1:173
- Gilbreth, Lillian (1878–1972), 2:208
- Gilleland, John, 1:185
- Gilpin, Thomas, 1:266
- Glass harmonica (Armonica), 1:30–32
 primary document: excerpt of Benjamin Franklin's letter describing the glass harmonica (1762), 1:32
- Glenn, John
 first manned satellite (Friendship 7) piloted by, 3:95
 Mercury 7 crew member, 3:88, 95
 oldest human to fly in space, 3:238
- Glenn, William, 3:180
- Glennan, Keith, 3:98, 137
- Glidden, Carlos, 2:155
- Glidden, Joseph F., 2:19–23
- Gliders, 2:165, 176–177
- Global Positioning System (GPS), 3:59–60
- Glover, Elizabeth (d. 1643), 1:32–33
- Goddard, Robert H., 2:312
- Godfrey, Thomas (1704–1749), 1:33–34
- Goeppert-Mayer, Maria (1906–1972), 3:60–61
- Gold-mining technologies, 1:231–232

- Golden Gate Bridge, 2:274–276
 primary document: letter of Charles Ellis to the *San Francisco Chronicle* (1930), 2:275–276
- Goldmann, Felix, 2:19
- Goldsmiths, 1:36, 180, 267. *See also* Iron- and silversmithing
- Goode, Sarah Elizabeth, 2:4, 68–70
- Goodhue, Lyle, 2:176
- Goodnight, Charles, 2:195–196
- Goodrich, B. F. (1841–1888), 2:75–76
- Goodyear, Charles (1800–1860), 1:232–233, 307–308
- Goodyear, Charles, Jr. (1833–1896), 2:76
- Google, 3:274–275
- Google Earth, 3:275–276
- Gorbachev, Mikhail, 3:164
- Gore, Al, 3:17, 39
- Gorelick (Ratley), Sarah, 3:88
- Gosling, James (1955–), 3:204
- Graham, Bette (1924–1980), 3:61–62
- Graham, Evarts Ambrose, 3:261
- Graham, Sylvester, 1:236
- Grain elevator, 1:233–234
- Gramophone/Victrola, 2:208–210
- Grandin, Temple (1947–), 3:276–277
- Gray, Elisha, 2:26–28, 323–324
- Gray, Mary, 3:20–21
- Great Depression and World War II (1930–1945), 2:251–257
 adhesive tape's popularity during, 2:241
 and automobile industry, 2:181–183, 204, 206, 207
 contribution to decline in railroad ridership, 1:290–291
 debut of Sunbeam's Mixmaster during, 1:222
 effect on farm equipment manufacturing, 1:206
 and end of Golden Age of amusement parks, 2:134
 and end of products and companies, 1:208; 2:210
 entertainment during, 2:255
 and food, 2:136, 145
 and Hoover, Herbert, 2:251
 and Hoover Dam, 2:251, 252, 277–283
 and labor response by Kellogg, William Keith, 2:88
 and radio, 2:237
 and Roosevelt, Franklin D., 2:251–254
 scientific advances during, 2:253–253
 and Tennessee Valley Authority (TVA), 2:251–252
 See also Dust Bowl; New Deal; Roosevelt, Franklin D.
- Great Exhibition of 1851 (London), 1:238; 2:162
 Colt Revolver at, 1:204
 equatorial sextant (solar compass) at, 1:225
 McCormick Reaper awarded grand prize at, 1:253
 omnibuses at, 1:265
 Otis elevator at, 2:139
 telegraph at, 1:310
- Greene, Catharine Littlefield (1755–1814), 1:116–117
- Grey, Henry, 2:140
- Gridiron for cooking, 1:234
- Griswold v. Connecticut*, 3:32
- Groves, Leslie R., 2:260
- Gumball machine, 2:210
- Gunsmiths, 1:174, 202, 203, 281, 243–244; 2:80. *See also* Iron- and silversmithing
- Gutenberg, Johann, 1:270–271
- Hadaway, William, 1:223
- Hall, David D., 1:1
- Hall, John, 1:74–75, 244, 281
- Halley, Edmund, 1:33, 96
- Hallidie, Andrew Smith (1836–1900), 2:76–77
- Halsted, William Stewart, 3:261
- Hamilton, Alexander, 1:8, 167; 3:128
 Report on Manufactures, 1:72, 138–139, 284
- Hamilton, Margaret (1936–), 3:62–63
- Hammes, John, 2:273
- Hammond, William, 1:187
- Han, Otto, 2:260
- Hanchett, Milton Waldo, 1:219
- Hand-cranked ice cream maker, 1:234–235
- Hanson, Alvah, 1:206
- Harley, Arthur, 2:221–222
- Harley-Davidson Motor Company, 2:221–222
- Harper, Frances Ellen Watkins, 1:201
- Hart, William, 1:230
- Harvard Computers, 2:77–79
 primary document: undated photo of Harvard Computers, 2:79
- Haslim, Leonard A., 3:254
- Hawking, Stephen (1942–2018), 3:277–278
- Hawkins, John Isaac, 1:16
- Haynes, Elwood (1857–1925), 2:79–80
- Haynes, Martha Euphemia Lofton (1890–1980), 3:63–64
- Hazen, Elizabeth, 3:5, 13–14
- Health reform, 1:235–237
- Heisenberg, Werner, 3:80, 305
- Helicopter, 2:276–277
- Helin, Eleanor Francis, 3:121
 primary document: press release naming Helin to WITI Hall of Fame, 3:122–123
- Henry, Benjamin Tyler, 1:174, 281
- Henry, Joseph (1797–1878), 1:78, 237–238
 biographical details, 1:237
 electric doorbell invented by, 1:199, 223
 and electromagnetic induction, 1:7, 237
 electromagnets designed by, 1:199, 237, 310
 electromechanical relay invented by, 1:169, 280
 and Morse, Samuel, 1:237, 261
 and National Academy of the Sciences, 1:238
 and Smithsonian Institution, 1:7, 237–238
 and U.S. Light-House Board, 1:237–238
- Henry rifle, 1:174
- Hershey, 2:173, 270, 300
- Hertz, Roy, 3:261

- Hewitt, Peter C. (1861–1921), 2:210–212
- Heydenfeldt, Solomon, 1:172–173
- Heyl, Henry (1842–1919), 2:80–81
- Hicks, Elias, 1:201
- High-pressure steam engine, 1:117–118
- Hilde, Libra R., 1:191
- Hillman, Bessie Abramowitz, 2:14–15
- Hillman, Sidney, 2:15
- Hinckley, Robert C., 1:178
- HIV. *See* AIDS research
- Hoe, Richard, 1:169, 271
- Hoffmann, Felix, 2:18–19
- Holland, James Frederick, 3:261
- Hoop skirt, 1:238–239
- Hoosier cabinet, 2:212
- Hoover, Erna, 3:143
- Hoover, Herbert, 2:88, 251
- Hoover Dam, 2:213, 277–283; 3:128
 environmental effects of, 2:213
 and Great Depression, 2:251, 252, 277–283
 primary document: Franklin D. Roosevelt’s dedication
 speech, 2:280–283
- Hopkins, Mark, 1:290
- Hopper, Grace (1906–1992), 3:1, 65–66
- Horse-drawn streetcar, 1:239–240
 primary document: image of horse-drawn streetcar (c. 1920),
 1:240
- Hospital Transport Service, Women’s Department, 1:240–241
- Hot air balloon, 2:176–177
- House, Royal E., 1:169, 272
- Howe, Elias (1819–1867), 1:241–242
 Automatic, Continuous Clothing Closure patent, 1:311
 biographical details, 1:241–242
 mechanized sewing machine patent, 1:5–6, 171, 242, 285,
 311
 patent battle with Singer, Isaac, 1:6, 285
 transverse shuttle invented by, 1:171, 303
- Howe, Richard, 1:65
- Howe, William, 1:242–243
- Howe truss, 1:242–243
- Hubble Space Telescope, 2:264; 3:278–279
- Hudson, Thomas, 1:54–55
- Hudson Canal Company, 1:245, 289
- Hudson Motor Car Company, 2:182
- Hudson River Rubber Company, 2:75
- Huggins, Charles Brenton, 3:261
- Hughes, Chris, 3:268
- Hughes, Howard, 3:42
- Hughes Aircraft, 3:2, 42
- Hull, Chuck, 3:316
- Hülsmeier, Christian, 2:309–310
- Human Genome Project, 3:279–380
- Human immunodeficiency virus (HIV). *See* AIDS research
- Humboldt, Alexander, von, 1:9, 46, 176
- Hungerford, David, 3:261
- Hunt, Walter
 breech-loading rifle designed by, 1:174, 284
 lockstitch sewing machine invented by, 1:170–171, 284,
 285
 Rocket Ball ammunition patented by, 1:281
 safety pin patented by, 1:285
- Hunter, John, 1:57
- Huntington, Collis, 1:275, 276, 290
- Huskey, Harry, 3:55
- Hyatt, Isaiah, 2:42–43
- Hyatt, John Wesley, 2:42–43
- Hybrid vehicles, 3:281–283
- Hydraulic fracturing (“fracking”), 3:66–67
- Hydroelectric power, 2:212–214
- Hydrogen bomb, 2:283
- Hydrogen energy, 3:67–68
- Hydroponics, 2:284–285
- Hypertext, 3:283
- Hypertext Markup Language (HTML), 3:165, 184, 208, 283,
 300
- Hypertext Transfer Protocol (HTTP), 3:165, 184, 208
- IBM 360 Computer, 3:17, 68–69
- IBM personal computer, 3:205–206
- Ice cream soda, 2:81–82
- In vitro fertilization (IVF), 3:70
- Indigo
 dyed jeans, 2:84–85
 experimentation of Lucas, Eliza, 1:3, 40, 41
 and slave labor, 1:71, 72
- Induction. *See* Electromagnetic induction
- Industrialism, Reconstruction, and the Gilded Age (1866–1900),
 2:1–7
 communication innovation, 2:7
 consumerism, 2:5–7
 defining issues, 2:1
 female entrepreneurship, 2:4–5
 industrialization of leisure, 2:5
 newspaper muckrakers, 2:2, 7, 172
 record number of patents, 2:1
 Reconstruction, 2:2–3
 public health and the modern city, 2:6–7
 Transcontinental Railroad, 2:3–4
- Infant formula, 3:206–207
- Inman, George (1895–1972), 2:82–83
- Insulin pump, 3:207–208
- Integrated circuit, 3:70–71, 76–77, 99–102, 132, 190, 192, 216
- Intel Corporation, 3:71–72
- Interchangeable gun parts, 1:243–244
- Interchangeable parts, 1:118–119
- Intercontinental ballistic missiles (ICBMs), 3:12, 239

- Minuteman I, 3:2
- R-7, 3:3
- Internal combustion engine, 1:119–121
 - development of, 2:119–121, 131–132, 181, 203
 - in hybrid vehicles, 3:281
 - steam engine replaced by, 1:149, 150
 - in submarines, 2:319
- International Ladies' Garment Workers' Union (ILGWU), 2:285–287
 - primary document: "The Uprising of the 20,000," 2:286–287
- International Space Station, 3:97, 105, 126–127, 166, 237–238, 283–285
- Internet, 3:208–209
 - ARPANET as forerunner to, 3:2–3, 16, 164, 190, 208, 300, 329
 - and Berners-Lee, Tim, 3:163, 165–166, 184–185
 - and net neutrality, 3:209
- Internet Explorer, 3:166, 190, 217, 301
- Internet Protocol (IP)
 - development of, 3:300
 - and early Internet, 3:17, 208
 - and 4G, 3:219
 - and packet switching, 3:17, 107
 - TCP/IP, 3:3, 107, 208, 300
- Interstate Highway System, 2:287–290
 - primary document: excerpt from the Federal-Aid Highway Act (1956), 2:289–290
- Intraocular contact lens, 3:285–286
- Inverted microscope, 1:244–245
- iPod, 3:286–287. *See also* Apple
- Iron ship with revolving turret, 2:83
- Iron- and silversmithing, 1:34–35
 - apprenticeships, 1:217
 - blacksmithing, 1:34–35
 - blacksmiths, 1:111, 163, 171, 209, 211, 217, 269; 2:156; 3:50
 - and cast-iron "Saugus pot," 1:54
 - in Colonial America, 1:3
 - and Conestoga tires, 1:209
 - and Deere, John, 1:171, 217, 269
 - definition of, 1:34
 - and Fitch, John, 1:111
 - and flexible catheter, 1:22
 - gunsmiths, 1:174, 202, 203, 281, 243–244; 2:80
 - and Michaux, Pierre, 2:156
 - and polished steel plow, 1:269
 - silversmiths, 1:22, 71, 111
 - and three-piece iron plow, 1:160
 - women as, 2:313–314
- Ironing board, 2:83
- Jackson, Andrew
 - and French and Indian Wars, 1:210
- Jacksonian democracy, 1:167
 - and Kentucky Rife in War of 1812, 1:35–36
 - and National Road, 1:134
 - and Panama Canal, 2:226
 - on Slater, Samuel, 1:147–148
 - urbanization and industrialization under, 1:235
- Jackson, Charles Thomas, 1:178
- Jackson, Janet, 3:323
- Jackson, Mary Winston (1921–2005), 3:72–74
 - biographical details, 3:72–73
 - career featured in *Hidden Figures* (film), 3:74
 - NASA's first black female engineer, 3:72, 73, 155
 - at West End Computers, 3:155
- Jackson, Michael, 2:118
- Jackson, Sandra Willett, 2:105
- Jackson, Thomas J. (Stonewall), 1:257
- Jackson, Thomas Penfield, 3:200, 301
- Jackson, Wes, 3:240
- Jacob, Mary Phelps (1891–1970), 2:214–215
- Janeway, Henry, 1:179
- Jarvik, Robert, 3:180
- Jarvik-7 artificial heart, 3:180
- Java, 3:287–290
 - primary document: interview with James Gosling, creator of Java (2001), 3:288–290
- Jeans, 2:84–86
- Jefferson, Thomas (1743–1826), 1:121–123
 - and agrarian versus manufacturing debate, 1:138, 139
 - American Philosophical Society member and president, 1:4, 8–9, 158
 - Dunbar and Freeman expedition ordered by, 1:4
 - federal banking system opposed by, 1:139
 - lap desk invented by, 1:4, 121, 122
 - Lewis and Clark Expedition ordered by, 1:4, 8, 45, 77, 123–125
 - moldboard plow invented by, 1:4, 122
 - Monticello, 1:122–123, 124, 141, 157–158, 162
 - and natural history, 1:4
 - and patent law, 1:135–137
 - primary document: excerpts from notes on wheel cipher, 1:163
 - Rush, Benjamin, eulogized by, 1:144
 - swivel chair invented by, 1:4, 157–158
 - wheel cipher invented by, 1:4, 162–163
- Jemison, Mae (1956–), 3:290–291
- Jencks, Joseph, 1:45, 54–55, 71, 76, 101, 136
- Jennings (Bartik), Betty Jean, 3:1, 56
- Jennings, Lewis, 1:281
- Jennings, Thomas L., 1:77
- Jervis, John B. (1795–1885), 1:245
- Jet Propulsion Laboratory (JPL), 3:74–75
 - Rocket Girls of JPL, 3:121–123
- Jobs, Steve (1955–2011), 3:80, 158, 163, 177–179, 209–213, 223, 244

- at Atari, 3:209, 244
- biographical details, 3:209–210
- and development of the iPhone, 3:212, 311–312
- and development of the iPod, 3:286
- NeXT, 3:178, 210, 213
- Pixar, 3:209, 210
- Jockstrap, 2:86
- Johnson, Andrew, 1:309
- Johnson, Clarence Kelly, 3:139–140
- Johnson, Edward H., 2:194–195
- Johnson, Eldridge, 2:29
- Johnson, Herbert, 1:222
- Johnson, Katherine Goble (1918–), 3:75–76, 155
- Johnson, “Lady Bird,” 2:289
- Johnson, Lyndon B., 2:105, 304
 - and Sentinel missile defense system, 3:239
 - War on Poverty, 3:106
- Johnson, Nancy M., 1:235
- Johnson, Willis, 1:222
- Johnson & Johnson, 1:175; 2:185; 3:196, 255
- Johnson Space Center, 3:105
- Joint United Nations Programme on AIDS (UNAIDS), 3:172–173
- Jones, Amanda T. (1835–1914), 2:86–87
 - primary document: “The Soldier’s Mother” by Amanda T. Jones (1867), 2:87
- Joystick/flight simulator, 3:291
- Kahn, Albert, 2:180
- Kahn, Robert, 3:3
- Kaposi’s sarcoma, 3:171, 173. *See also* AIDS research
- Kare, Susan (1954–), 3:213
- Keen, William W., 1:188
- Kellogg, William Keith (1860–1951), 2:88–89
- Kelly, Michael, 2:4
- Kelly, William (1811–1888), 2:89–90
- Kennedy, John F.
 - and Apollo Project, 3:14, 95
 - and Communications Satellite Act (1962), 3:42
 - and Operation Ranch Hand (Vietnam War herbicidal warfare program), 3:9
 - and Partial Test Ban Treaty (1963), 3:111
 - testing touch-tone phone at Seattle World’s Fair, 3:145
 - “Urgent National Needs” speech (1961), 3:4, 95
- Kennedy Space Center, 3:97, 237–238, 290
- Kenschaft, Patricia, 3:20
- Kentucky long rifle, 1:35–36
- Kettering, Charles F. (1876–1958), 2:204–205, 215–216, 219
- Kevlar. *See* Bulletproof vest/Kevlar
- Kier, Samuel (1813–1874), 2:90–91
- Kilby, Jack (1923–2005), 3:70–71, 76–77, 100, 215–216
- Kindle e-book reader, 3:251, 258, 265, 312
- Kinematoscope, 2:6, 59, 91, 103, 243
- Knight, Margaret (1838–1914), 2:91–92
- Know-Nothing Party, 1:171
- Knox, Rose Markward, 2:4
- Kolbe, Hermann, 2:18
- Kolff, Willem, 3:180
- Koop, C. Everett, 3:173–177
- Kurzweil, Ray (1948–), 3:291–292
- Kwolek, Stephanie Louise (1923–2014), 3:77–78
- Labor and labor unions
 - Amalgamated Clothing and Textile Workers Union (ACTWU), 2:15
 - Amalgamated Clothing Workers of America (ACWA), 2:14–16
 - American Federation of Labor (AFL), 2:15, 286
 - Baltimore Buttonhole Makers Union, 2:15
 - Chicago Men’s Garment Workers Strike, 2:14–15
 - child labor, 1:162, 298; 2:2, 7, 104–105
 - Congress of Industrial Organizations (CIO), 2:15
 - Factory Girls’ Association, 1:129
 - and Ford, Henry, 2:204
 - International Garment Workers of America, 2:4–5
 - International Ladies’ Garment Workers’ Union (ILGWU), 2:285–287
 - Lady Stitchers’ Union, 2:4, 92–93
 - Lowell Female Labor Reform Association (LFLRA), 1:129, 297–298
 - Operation Dixie (campaign to unionize Southern workers), 2:15
 - Ten-Hour Movement, 1:297–299
 - UNITE HERE, 2:15
 - United Garment Workers of America (UGW), 2:14–16
 - Workers United, 2:15
- Lackoff, Sam, 3:24
- Lacks, Henrietta (1920–1951), 3:78–79
- Lady Stitchers’ Union, 2:92–93
- Lam, Tat, 3:215
- Lamarr, Hedy (1914–2000), 2:290–292
 - primary document: patent for Hedy Lamarr’s Frequency-Hopping System (1942), 2:292
- Land mines, 1:245–246
- Land, Edwin H. (1909–1991), 3:79–80, 117–118
- Lange, Dorothea (1895–1965), 2:292–293
- Larson, John, 2:216–217
- Laser cataract surgery device, 3:213–214
- Lasers, 3:80
- Lavoisier, Antoine, 1:51
- Lawn mower, reel-type, 2:93
- LED lights, 3:81
- Lee, Linda, 3:121
- Lee, “Mother” Ann, 1:196
- Lend-Lease Program (1941–1945), 2:293–294
- Lennox, David (1855–1947), 2:93–94

- Leroux, Henri, 2:18
- Letterman, Jonathan, 1:187–188, 241
- Lewis, Alice Jackson, 1:201
- Lewis, Craig, 3:181
- Lewis, Meriwether, 1:8, 123–125. *See also* Lewis and Clark Expedition
- Lewis and Clark Expedition (1804–1806), 1:123–125
- American Philosophy Society sponsorship for, 1:124
 - artifacts housed in Peale Museum, 1:48
 - geographic and geological findings of, 1:125
 - and Jefferson, Thomas, 1:4, 8, 45, 77, 123–125
 - political goals of, 1:123
 - primary document: excerpts from expedition journal (1805, 1806), 1:126–127
 - Sacagawea as guide to and voting member of, 1:23, 125
 - scientific goals of, 1:123–124
 - scientific observations and discoveries of, 1:124–125
 - social science contribution of, 1:125
 - York (African American slave) as voting member of, 1:125
- Li, Min Chiu, 2:261
- Liberty Ships, 2:294–295
- Lichterman (Teitelbaum), Ruth, 3:1, 56
- Lie detector, 2:216–217
- Life Savers candy, 2:217
- Lightning rod, 1:36–37
- primary document: frontispiece and title page of Benjamin Franklin's *Experiments and Observations on Electricity* (1774), 1:37
- Lilienthal, Otto, 2:165, 176
- Lincoln, Abraham, 1:138, 167, 285, 308–309
- assassination of, 1:273
 - and construction of U.S. Capitol, 1:305
 - first transcontinental telegraph wire received by, 1:296
 - floating dry dock patented by, 1:113–114, 228–230
 - and Pacific Railway Act (1862), 1:258
 - primary document: excerpt from patent application for floating dry dock (1849), 1:229–230
 - and steam locomotive, 1:288–290
 - and telegraph, 1:257, 296, 310–311
- Lindbergh, Charles, 2:175, 178, 190
- Ling, Helen, 3:121–122
- Linotype machine, 2:94–95
- Linux, 3:221, 292–293
- Liotta, Domingo, 3:181
- Lipman, Hymen, 1:267
- Liquified natural gas (LNG) carrier, 3:82
- Liskov, Barbara (1939–), 3:82–83
- Literacy
- reading, 1:33, 169, 171, 191; 2:54, 285; 3:201, 295
 - technology, 3:177, 256
- Lobster trap, 1:127
- Lockheed Martin, 2:178
- primary contractor for Terminal High Altitude Area Defense (THAAD), 3:12
 - space shuttle external tank constructed by, 3:237
 - stealth technology developed by, 3:139–140
- Long, Crawford Williamson (1815–1878), 1:178, 246–247
- biographical details, 1:246–247
 - pioneer of use of sulfuric ether for anesthesia, 1:178, 246–247
- Long arm. *See* Extension arm
- Loom, 1:38–40
- primary document: excerpts from diary of Martha Ballard describing home weaving (1787), 1:39–40
- Loughead, Malcolm, 2:182
- Love, Nancy Harkness, 2:261, 331–332
- Love, William, 2:108
- Love Canal, 2:108
- Lovelace, William Randolph, II, 3:88
- Lowell, Francis Cabot, 1:5, 74, 128, 161–162
- Lowell mill system, 1:5, 61, 74, 128–130, 161–162
- Factory Girls' Association, 1:129
 - Lowell Female Labor Reform Association (LFLRA), 1:129, 297–298
 - primary document: description of the life of a mill girl (1845), 1:129–130
 - Ten-Hour Movement, 1:297–299
- Lucas, Eliza (1722–1793), 1:40–42, 45
- indigo experimentation of, 1:3, 40, 41
 - primary document: letter of Eliza Lucas to her father (1741), 1:41–42
- Lucas, George
- Skywalker Ranch, 3:134–135
 - Strategic Defense Initiative named after *Star Wars*, 3:239
- Lyceum Movement, 1:168
- Lyman, William Worcester, 2:4, 33–34
- M&M's, 2:295, 300
- M4 Sherman Tank, 2:295–296
- M16 Rifle, 3:83–84
- MacDonald, Thomas, 2:257, 287
- Machine/Gatling gun, 1:247–249
- Macintosh, Charles, 3:115–116
- Madison, James, 1:87
- and canal building, 1:6
 - First Bank allowed to expire under, 1:139
 - on intellectual property law, 1:136
 - on tariffs, 1:138
- Magnetic resonance imaging (MRI), 3:84–85
- Maher, Mary Denis, 1:191
- Maker Faire, 3:254, 293–295
- Manhattan Project, 2:201, 260, 264, 272, 296–297; 3:60–61, 111, 220
- and Calutron Girls, 2:267–268
 - and Oppenheimer, J. Robert, 2:303–304
 - and Wu, Chein-Shiung, 2:333–334
- Manifest destiny, 1:78, 171
- Mann, Horace, 1:169

- March for Science, 3:295
- Marconi, Guglielmo, 2:5, 171, 236
- Marcus, Siegfried, 2:181
- Margarine, 2:95
- Markkula, Mike, 3:177
- Mars Rover Series, 3:295–297
- Marsh, Albert L. (1877–1944), 2:217–218
- MASER, 3:85
- Masking tape, 1:175; 2:113, 218, 241. *See also* Adhesive tape
- Mason, John Landis
 mason jar invented by, 1:173–174, 249
 salt shaker invented by, 1:267
- Mason jar, 1:173–174, 249
- Masters, Sybilla (c. 1675–1720), 1:42
- Matchbook matches, 2:96
- Mather, Cotton (1663–1728), 1:43–44
- Matulka, B. Rebecca, 3:50–53
- Matzeliger, Jan Ernst (1852–1889), 2:4, 96–97
- Mauchly, John, 3:55, 150–151
- Maxim, Hiram, 1:247–249
- Maxim, Hudson (1853–1927), 2:97
- Maynard, Edward (1813–1891), 1:249–250
- Maynard carbine, 1:250–252
- McClintock, Barbara (1902–1992), 3:86–87
- McCormick, Cyrus (1809–1884), 1:252–254
 primary document: letter from Robert E. Lee regarding
 curriculum at Washington College (1865), 1:253–254
- McCormick, Katherine, 3:31
- McKnight, William L. (1887–1978), 2:218–219
- McLuhan, Marshall, 1:168
- McNeill, Thomas E., 1:222
- McNulty (Mauchly Antonelli), Kathleen “Kay,” 3:1, 56
- Mead, Margaret (1901–1978), 2:297–299
- Mechanical reaper, 1:254–255
- Mercury 13, 3:88
- Merlin, John Joseph, 1:282
- Merrick, Solymon (1806–1852), 1:255
- Metal detector, 2:97–98
- Metal electrode weld, 2:98–99
- Metal windmill, 2:99–100
- Metcalf, Robert (1946–), 3:214–215
 American Arithmometer Company financed by, 2:14
 coinventor of Ethernet, 3:215
 Metcalf’s Law, 3:214
 3Com founded by, 3:215
- Microchip, 3:215–217
- Microsoft, 3:217–218
 competition with Intel, 3:72
 competition with Linux, 3:293
 Internet Explorer, 3:166, 190, 217, 301
 MS-DOS, 3:200, 206, 211, 217
 Windows, 3:166, 200, 211, 217–218, 251–253, 286, 301
 See also Gates, Bill
- Microwave oven, 2:299
- Midgley, Thomas (1889–1944), 2:204–205, 219–220; 3:38
- MIDI (Musical Instrument Digital Interface), 3:297
- Miescher, Friedrich, 3:4, 202
- Military-industrial complex, 3:88–90
 and “big science,” 2:264
- Military technology (Civil War), 1:255–258
 amputations, 1:256
 medical history, 1:256
 photographic documentation, 1:256
 railroad’s impact, 1:257–258
 sanitation, 1:256
 submarines, 1:257
 surgery, 1:256
 systems, 1:256
 telegraph’s impact, 1:256–257
 weaponry, 1:256
- Military technology (post–Civil War through World War I),
 2:100–102
 air balloons, 2:101
 aircraft in WWI, 2:75, 171, 176, 178, 234; 3:48
 machine guns, 2:102
 medical technology, 2:102
 minié bullets, 2:101
 railroad’s impact, 2:101
 submarines, 2:101
 tanks, 2:101
 telegraph’s impact, 2:102
- Military technology (World War II), 2:299–301
 aircraft, 2:189, 223, 234, 255–256, 261–262, 300, 301; 3:7
 ammunition, 2:300
 atomic bombs, 2:300 (*see also* Atomic bombs/nuclear
 weapons)
 DDT, 2:301
 food and nutrition, 2:300
 health and medicine, 2: 300–301
 nylon, 2:301
 radar, 2:300, 301–302, 310, 320
 sonar, 2:300
- Miller, Phineas, 1:99–100, 117, 164, 165
- Miller, Samuel, 1:84
- Milliken, Greg, 3:168
- Milling machine, 1:130–131
- Minuteman I (ICBM), 3:2
- Minsky, Marvin (1927–2016), 3:90–91
- MIT Radiation Laboratory, 2:301–302
- Mitchell, Maria (1818–1889), 1:19, 258–259
- Mobile phone, 3:218–219
- Molina, Mario J., 2:176; 3:38
- Moll, Gerard, 1:199
- Monroe, James, 1:260
- Monroe, Rose Will, 2:314
- Monroe Doctrine, 1:168

- Monsanto, 2:136; 3:9, 19, 172, 273
 Montagnier, Luc, 3:172, 175
 Montague, Hannah Lord, 1:219–220
 Monte Carlo method (computer algorithms), 3:56, 289
 Montgolfier brothers, 2:176
 Moody, Paul, 1:74
 Moog, Robert (1934–2005), 3:91–92
 Moore, Ann (1934–), 3:298
 Moore, Gordon, 3:71–72, 100, 101, 131, 217
 Moore, Hiram, 1:171, 205
 Moore, John Hamilton, 1:137
 Moore's Law, 3:71, 132, 133, 217, 289
 Morey, Samuel (1762–1843), 1:76, 131–132, 148
 Morgan, Garrett (1877–1963), 2:220–221
 Morgan, J. Pierpont, 2:2, 35, 36–37, 58, 61, 74, 107, 160, 169, 324
 Morgan, Mary Sherman (1921–2004), 3:92–93
 Morphine, 2:59
 as anesthesia, 1:179, 187
 discovery of, 1:178
 wartime use of, 1:187
 Morrison, William J.
 cotton candy invented by, 2:45
 first electric car designed by, 3:49, 50, 247
 Morse, Samuel F. B. (1791–1872), 1:78, 260–261; 2:120
 biographical details, 1:260
 correspondence with Mitchell, Marie, 1:259
 and Henry, Joseph, 1:237
 inspired by Humboldt, Alexander von, 1:46
 and telegraph line/cable, 1:202, 226, 260, 261–262, 295
 telegraph invented by, 1:7, 226, 256, 260, 261–262, 236
 See also Morse code
 Morse code, 1:7, 169, 257, 260, 261–262, 295; 2:236, 323; 3:25, 328
 Motion picture camera, 2:102–104
 Motorcycle (pre–World War II), 2:221–222
 Motorcycles, 1:120, 121; 3:36
 Motorola, 2:182, 205–206
 MP3, 3:298–299
 Muller, Paul Hermann, 3:6
 Multitubular boiler, 1:132
 Mural, Frank, 3:55

 Nanotechnology, 3:93–94
 Napalm, 3:94
 Nash-Kelvinator Corporation, 2:182
 National Academy of Sciences (NAS), 1:262–263
 National Advisory Committee for Aeronautics (NACA), 2:223
 National Aeronautics and Space Administration (NASA), 3:94–98
 centers and facilities, 3:97
 creation of, 3:94–95
 primary document: letter of Dwight Eisenhower to Keith Glennan (1960), 3:98
 Project Mercury, 3:88, 95, 96
 Skylab, 3:97, 133–134, 284
 and space science, 3:96
 Terra, 3:96–97
 See also Apollo Project; International Space Station; Space shuttle program; Voyager spacecraft
 National Consumers League, 2:104–105
 National Institutes of Health (NIH), 2:6, 105–106; 3:98, 119
 AIDS research, 2:105; 3:173, 175
 artificial heart program, 3:180
 Human Genome Project funded by, 3:279–280
 Rocky Mountain Labs, 2:240
 National Oceanic and Atmospheric Administration (NOAA), 1:78; 3:144
 National Road, 1:132–134
 National Science Foundation (NSF), 3:98–99
 Nativism, 1:171
 Natural history, 1:44–46
 Natural philosophy, 1:4, 8–9, 31, 44, 237
 Needham, Orwell H., 1:182
 Negroponte, Nicholas (1943–), 3:299–300
 Neoprene, 2:302–303
 Netscape, 3:166, 190, 256, 274, 300–301
 New Deal, 2:213, 251–257
 and Ford, Henry, 2:204
 and Lange, Dorothea, 2:292–293
 Tennessee Valley Authority Electricity Project (TVA), 2:213, 251–252, 328–329
 union support for, 2:286
 Works Progress Administration, 2:213
 See also Hoover Dam
 New Millennium (2000–present), 3:247–254
 alternative energy sources, 3:247–248
 bioprinting, 3:248
 electric cars, 3:247
 laser technology, 3:248
 medical technology, 3:249–250
 open-source software, 2:252
 portable technology, 2:253–254
 search engine technology, 2:252–253
 technology in education, 3:250–251
 technology in music, 3:251–252
 3-D technology, 3:248–249
 New Republic and the Market Economy (1780–1820), 1:71–79
 African technologies, 1:71
 agricultural innovation, 1:73–74
 amateur scientists, 1:77–78
 attitudes toward science, 1:71–72
 Census Act (1790), 1:73
 factory system, 1:74
 immigration's significance, 1:71–72, 74, 76–77

- interchangeable parts, 1:75–76
- medical sciences, 1:75
- shipbuilding, 1:73
- steam power, 1:76–77
- transportation engineering, 1:75–76
- Newbold, Charles, 1:73, 159
- Newton, Isaac, 1:27, 33, 68, 103, 144
- Niagara Falls Power Plant, 2:106–112
 - primary document: excerpt from Nikola Tesla’s commemoration address (1897), 2:108–112
- Niépcé, Joseph Nicéphore, 2:31–32
- Nightingale, Florence, 1:88, 89, 187, 256, 263–264, 307
- Nightingale Plan, 1:263–264, 307
- 911 emergency system, 3:8–9
- Noether, Amalie Emmy (1882–1935), 2:224–225
- North, Simeon (1765–1852), 1:76, 243, 264–265
- Nowell, Peter, 3:261
- Noyce, Robert (1927–1990), 3:71–72, 77, 99–102, 131, 215–216
 - primary document: personal interview for the IEEE History Center (1975), 3:100–102
- Nuclear and radiation accidents, 3:102–104
- Nuclear energy/nuclear power plants, 3:219–221
- Nuclear weapons. *See* Atomic bombs/nuclear weapons
- Nye, Bill (1955–), 3:302
- Nystatin, 3:5, 13–14. *See also* Antibiotic

- Obama, Barack, 3:34, 41, 53, 76, 226
 - and Keystone XL pipeline, 3:114
 - napalm ban signed by, 3:94
 - One Maker Faire hosted by, 3:294
- Obama, Michelle, 3:291
- Obsolescence, 2:207; 3:22, 163, 168
- Ochoa, Ellen (1958–), 3:105–106
- Odometer, 1:135
- Office technology (pre–World War II), 2:112–114
- Olds, Ransom Eli (1864–1950), 2:225
- Olmsted, Frederick Law, 2:6, 162, 167, 174
- Olson, Richard, 3:255
- Omnibus System, 1:265–266
- One Laptop per Child, 3:302–303
- Onesimus (fl. 1706–1716), 1:46–47
- oN-Line System (NLS), 3:3
- Onion Router. *See* TOR (The Onion Router)
- Open-source software, 3:221–222
- Oppenheimer, J. Robert (1904–1967), 2:272, 296–297, 303–304, 316; 3:111
- Orshansky, Mollie (1915–2006), 3:106–107
- Orwell, George, 3:169–170, 210
- O’Sullivan, John L., 1:171
- Otis, Elisha Graves, 1:224–225, 256–257; 2:139, 162, 201
- Otis, William, 1:168, 291–292
- Otis Elevator Company, 1:224–225, 256–257; 2:65–66
- Owens, Michael, 2:190–191

- Pacific Railroad Act, 1:276–279; 2:3, 153
- Pacific Telegraph Act (1860), 1:7, 296
- Packet switching, 3:107–108
- Packing tape, 1:175. *See also* Adhesive tape
- Paine, Thomas, 1:76
- Panama Canal, 2:143, 163, 172, 225–232, 279
 - primary document: excerpt from Theodore Roosevelt’s message to Congress after Returning from Canal Zone (1906), 2:228–232
- Paper bag, 2:114
- Paper clip, 2:114–115
- Papermaking machine, 1:266
- Parmly, Levi Spear, 1:75, 102
- Particle accelerator, 3:108–110
 - primary document: press release issued by CERN, the European Organization for Nuclear Research (2012), 3:109–110
- Pascal, Blaise, 1:265
- Patent and copyright statutes, 1:135–137
 - Copyright Act (1790), 1:136
 - and music, 3:298
 - Patent Act (1790), 1:136
 - Patent Act (1836), 1:170
- Paul, Les (1915–2009), 2:270–271, 304–305
- Pauling, Linus “Carl” (1901–1994), 3:34, 110–111
- PayPal, 3:303–304
- Peabody, Elizabeth Palmer, 1:168, 170, 259
- Peale, Charles Willson (1741–1827), 1:47–51
 - primary document: letter to Thomas Jefferson regarding agricultural innovations (1815), 1:48–51
- Pemberton, John “Doc,” 2:43–44
- Pencil eraser, 1:267
- Penicillin, 2:6, 256–257, 300–301, 306–307; 3:5, 13
- Penn, Sean, 3:134–135
- Penn, William
 - Charter of Privileges (1701), 1:10
 - Governor’s Mill built for, 1:42
 - scientific legacy of, 1:72
- Pennington, Mary Engle (1872–1952), 2:232
- Pepper (and salt) shaker, 1:267
- Perkins, Jacob (1766–1849), 1:76, 161, 267–268
- Perkins, William C., 1:234
- Perlman, Radia (1951–), 3:222–223
- Permanent press fabric, 3:111–112
- Personal computer (PC), 3:223–224
- Petroleum industry (post–World War II), 3:112–114
- Petroleum industry (pre–World War II), 2:233–234
- PGP Encryption, 3:303–304
- pH Meter, 2:307–308
- Phelps, George M., 1:272

- Phonograph, 2:115–119, 208–210
 and Bell, Alexander Graham, 2:117, 209
 invented by Edison, Thomas, 2:115–118, 208–210
 primary document: roll call of companies at the
 Phonograph Convention in Chicago (1890), 2:119
- Photocopier, 2:307–308
- Photographic film, 2:120–121
- Photography. *See* Camera
- Pierce, William, 1:11
- Pinball and arcade games, 2:308–309
- Pinckney, Eliza Lucas. *See* Lucas, Eliza
- Pincus, Gregory, 3:31
- Pipe wrench, 2:121
- Piria, Raefele, 2:18
- Pixii, Hippolyte, 2:9
- Plasma arc welding, 3:114–115
- Plastic wrap, 2:256, 301, 309
- Plastics, 3:115–117
- Platform scale, 1:168, 268–269
- Player piano, 1:121–122
- Pneumocystis carinii pneumonia (PCP), 3:171, 173. *See also*
 AIDS research
- Polaroids, 3:79–80, 117–118
- Polio vaccine, 3:54, 118–119, 124, 125–126, 152
- Polished steel plow, 1:269
- Pong, 3:20–22, 119–120, 321, 325
- Poplawski, Stephen J., 2:189
- Pop-up toaster, 2:234–235
- Portable transistor radio, 3:120–121
- Portland cement mortar, 2:122–123
- Post-Cold War Era (1980–1999), 3:163–170
 ARPANET and Internet, 3:164–165
 cloning, 3:166
 computer browsers, 3:166
 computers, 3:165–166
 consumer electronics, 3:166–167
 consumerism and choice, 3:163–167
 entertainment advances, 3:167
 hacking, 3:168
 journalism and information transmission, 3:168
 mobile phones, 3:167
 myth of “millennium meltdown” (Y2K), 3:169
 myth of “paperless office,” 3:168–169
 obsolescence, 3:163, 168
 and Orwell, George, 3:169–170
 rate of technological innovation, 3:163
 smart car technology, 3:167–168
 and Soviet Union, 3:163–164
- Practical ocean navigation, 1:137–138
- Priestley, Joseph (1733–1804), 1:51–52
 biographical details, 1:51
 carbonated water created by, 1:51; 2:141
 influence on study of ecology, 1:51
 nitrous oxide experiments, 1:178
 oxygen discovered by, 1:51
- Printing, 1:269–271
 electric typewriters, 2:173; 3:61–62, 69
 first printing press in America, 1:32–33
 Gutenberg’s printing press, 1:270–271
 history of, 1:270–271
 Jefferson’s portable printing press, 1:122
 laser printing, 1:271; 3:159, 249
 Linotype machine, 2:94–95
 movable type, 1:270
 photocopying, 2:307; 3:158–160, 168
 QWERTY keyboard, 2:155–156
 rotary printing press, 1:169, 174
 typewriter, 1:271; 2:5, 155–156
 woodblock printing, 1:270
 See also 3-D printing
- Printing telegraph, 1:169, 271–272, 310
- Progressive Era and the Roaring Twenties (1900–1929),
 2:169–175
 automobile advances, 2:169–170
 communications and media advances, 2:171
 daily life advances, 1:172–173
 film and photography, 2:171
 health-related advances, 2:175
 medical and health advances, 2:172–173, 175
 Panama Canal, 2:172
 Taylorism, 2:146–147, 170, 208
 technological challenges of urbanization, 2:173–175
 transportation advances, 2:169–170
 and wealth, 2:171–172
 Wright brothers’ inaugural airplane flight, 2:170–171
- Pullman, George Mortimer (1831–1897), 1:273, 290
- Pullman car. *See* Railroad sleeping car
- Punch card tabulator, 2:123
- Pure Food and Drug Act (1906), 3:18
- Puritanism, 1:2, 12, 43, 72, 85–86
- Pushpin, 2:113, 235–236
- Putting-out production system, 1:4, 5
- Quadruplex telegraph, 2:124–125
- Quakerism, 1:13, 42, 44–45, 72, 101, 201
- Quantum science, 3:304–305
- Queeney, John Francis, 2:136
- Quinby, Moses, 1:24
 primary source: excerpt from *Mysteries of Bee-Keeping Explained* on use of bee smoker, 2:24–25
- QWERTY layout. *See* Typewriter and QWERTY
- Radar, 2:309–310
- Radio, 2:236–240
 primary document: “Radio’s Real Uses” by E. E. Free,
 science editor for *The Forum* (1926), 2:239–240

- Radioplane Company, 3:48
- Railroad refrigerator car, 2:125–126
- Railroad sleeping car and Pullman car, 2:126–127
- Railroad switch systems, 2:127–128
- Railroad T-rail and tie, 1:168, 273–274, 293
- Railroads, 1:274–279
- Pacific Railway Act (1862), 1:258
 - primary document: Pacific Railway Act (1862), 1:276–279
 - Transcontinental Railroad, 1:208–209, 258, 275, 288–289, 296; 2:3, 153–155
 - and war, 1:257–258, 275; 2:101
- Rains, Gabriel, 1:245–246
- Ratchet wrench, 1:279–280
- Reagan, Ronald, 3:59, 89–90, 100, 173–175, 245
- and International Space Station, 3:280
 - and Strategic Defense Initiative (SDI or “Star Wars”), 3:12, 90, 239–240
- Reed, Ezekiel, 1:76
- Refrigerator, 2:310–311
- Relay, 1:280
- Remington Rand, Inc., 3:1, 151, 189
- Repeating rifle, 1:280–282
- Report on Manufactures* (1791), 1:72, 138–139, 284
- RFID labels, 3:305–307
- Richards, Ellen Swallow (1842–1911), 2:128–129
- Richardson, J. J., 1:280
- Richter scale, 2:311
- Rickover, Hyman, 3:128–129
- Ride, Sally (1951–2012), 3:224–226
- Ritchie, Dennis (1941–2011), 3:226–229, 313–316
- primary document: abstract for “The Development of the C Language” by Dennis Ritchie (1993), 3:227–229
- Rittenhouse, David (1732–1796), 1:8, 28, 52–54, 45, 73, 137
- biographical details, 1:52
 - diffraction grating created by, 1:52, 103–104
 - primary document: letter from Thomas Jefferson (1778), 1:53–54
- Ritty, James, 2:42
- River steamer, 1:139–140
- RNA (ribonucleic acid), 3:4
- Robber barons, 1:276; 2:34
- Robbins, Frederick C., 3:4, 54
- Roberts, Macie, 3:121
- Roberts, Nathan, 1:76
- Robotic surgery, 3:229–232
- primary document: letter from Acting District Director of the FDA to President of Intuitive Surgical Inc. on the regulation of robotic surgery (2013), 3:230–232
- Rock, Arthur, 3:71
- Rock, John, 3:31–32
- Rockefeller, John D., 2:2, 160
- Rocket Girls of JPL, 3:121–123
- primary document: press release announcing Eleanor F. Helin’s naming to WITI Hall of Fame (1998), 3:122–123
- Rocketry (pre–Space Age), 2:311–313
- Rocky Mountain Laboratories, 2:240
- Roebbling, Emily (1843–1903), 2:129–133
- biographical details, 2:129
 - primary document: photograph of promenade on Brooklyn Bridge, 2:131
 - role in construction of Brooklyn Bridge, 2:30, 129–131, 132
- Roebbling, John (1806–1869), 2:30–31, 131–132
- biographical details, 2:131
 - designer of Brooklyn Bridge, 2:131–132
- Roebbling, Washington A., 2:30, 130, 132
- Rogallo, Francis Melvin (1912–2009), 3:123–124
- Rohwedder, Otto Frederick, 2:191
- Roll film, 2:133
- Roller coaster, 2:133–134
- Roller skates, 1:282–283
- Roosevelt, Eleanor, 2:104, 331
- Roosevelt, Franklin D.
- as assistant secretary of the navy, 2:223
 - and Carver, George Washington, 2:40
 - and Einstein, Albert, 2:201, 260, 272
 - Executive Order 8802 (prohibiting racial discrimination in the national defense industry), 3:154
 - and England’s Tizard Mission, 3:331
 - first American president to appear on television, 2:163
 - fireside chats, 2:237, 254
 - and Ford, Henry, 2:204
 - and Hoover Dam, 2:279, 280–283
 - and interstate highway system, 2:287
 - and Lend-Lease Act, 2:293–294
 - and Manhattan Project, 2:202, 260, 272, 296
 - and MIT Radiation Laboratory, 2:301–302
 - and National Cancer Act (1937), 3:261
 - primary document: Hoover Dam dedication speech, 2:280–283
 - Rural Electrification Administration (REA) created by, 2:252
 - shift from “Dr. New Deal” to “Dr. Win the War,” 2:256
 - and Tennessee Valley Authority Electricity Project (TVA), 2:328
 - See also* New Deal
- Roosevelt, Nicholas, 1:76–77, 293
- Roosevelt, Theodore
- Bureau of Reclamation established under, 2:277–278
 - as first modern president, 2:7
 - and military-industrial complex, 3:89
 - New Nationalism of, 2:172
 - opposition to ban on saccharine by, 2:136; 3:18
 - and Panama Canal, 2:227–232
 - primary document: excerpt from message to Congress after returning from Panama Canal Zone, 2:228–232
 - and Reclamation Act (1902), 2:278
- Root, Elisha K., 1:202–203, 204
- Ropes, Hannah, 1:190
- Rosie the Riveter, 2:313–316

- primary document: excerpt from interview with Maria Isabel Solis (2003), 2:315–316
- Rotary hook (for sewing machines), 1:283
- Rotary washing machine, 2:134–135
- Rotheim, Erik, 2:176
- Rous, Francis Peyton, 3:261
- Rowing machine, 2:135
- Rowland, Frank Sherwood, 2:176; 3:38
- RU-486/Plan B, 3:307–308
- Rucker ambulance, 1:283–284
- Rudy, Marion Frank, 3:11
- Ruggles, John, 1:170
- Rumford Fireplace, 1:141, 158–159
- Rumsfeld, Donald, 3:19
- Rush, Benjamin (1746–1813), 1:142–145
primary document: excerpt from medical writings of Benjamin Rush (1805), 144
- Sabin, Albert B. (1906–1993), 3:54, 119, 124–125
- Saccharine, 2:135–137; 3:18
controversy and regulation, 2:136–137
and Roosevelt, Theodore, 2:136; 3:18
Sweet’ n Low (brand name), 2:137, 3:18
- Safety pin, 1:284
- Safety razor, 2:240–241
- Salicylic acid. *See* Aspirin
- Salk, Jonas (1914–1995), 3:54, 119, 124, 125–126, 152
- Salt shaker. *See* Pepper (and salt) shaker
- Sänger, Eugen, 3:237
- Sanger, Larry, 3:250
- Sanger, Margaret, 3:31
- Saquinavir, 3:172. *See also* AIDS research
- Sarnoff, David, 2:171
- Satellite radio, 3:232–233
- Satellites and space probes, 3:126–127
- “Saugus pot,” 1:54–55
- Scheele, Carl Wilhelm, 1:51
- Schenck, John F., 1:78
- Schlatter, John, 3:18
- Schooner, 1:55–56
- Schultz, Jane E., 1:190–191
- Schwinger, Julian (1918–1994), 2:316–317
- Science Friday*, 3:308
- Scientific management (Taylorism), 2:146–147, 170, 208
- Scotch Tape, 2:113, 218, 241. *See also* Adhesive tape
- Scott, Charlotte, 3:20
- Scott, Ewin, 2:134
- Scott, Mike, 3:177
- Scott, Richard, 2:330
- Scott, Thomas, 2:34
- Scott, Walter, 2:47–48
- Scott, Winfield, 1:213
- Screw-cutting lathe, 1:145
- Sculley, John, 3:177–178
- Seaborg, Glenn, 2:260
- Self-driving cars, 3:233
- Selfridge, Thomas, 2:178
- SEMATECH, 3:234–235
- Simple, Ellen Churchill (1863–1932), 2:317–318
- Sertürner, Friedrich, 1:178
- SETI (Search for Extraterrestrial Intelligence), 3:308–311
- Seward, William, 1:10
- Sewell, William, 3:180
- Sewing machine, automated, 1:284–286
- Sewing pattern, 1:286–287
- Shapiro, Bob, 3:19
- Sharecropping, 2:3
- Sharpless, Thomas Kite, 3:55
- Shaw, Robert F., 3:55
- Shepard, Alan, 3:4, 88
- Sherman, Patsy O’Connell (1930–2008), 3:127–128
- Shippingport Atomic Power Station, 3:128–129
- Shockley, William, 3:1, 131, 148
- Sikorsky, Ivan, 2:276–277
- Silent Spring* (1962), 2:288–289; 3:6–7, 18, 36–38, 129–130.
See also Carson, Rachel (1907–1964)
- Silicon Valley, 3:130–132
- Silo, 2:137–138
- Silver, Bernard, 3:25
- Silverman, Jacob, 3:93
- Simms, Frederick, 2:183
- Singer, E. C., 1:288
- Singer, Isaac
first commercially viable sewing machine developed by, 1:6, 285–286
marketing skills of, 1:285
patent battle with Howe, Elias, 1:6, 285
- Singer Sewing Machine Company, 1:285, 303; 3:25
- Single-chip microprocessor, 3:132–133
- Skylab, 3:97, 133–134, 284
- Skyscraper, 2:138–140
- Skywalker Ranch, 3:134–135
- Slater, Hannah Wilkinson (1775–1812)
Almy, Brown, & Slater, 1:101
first woman to receive U.S. patent (two-ply cotton thread), 1:5, 74, 101
Quaker background of, 1:45, 101
- Slater, Samuel (1768–1835), 1:5, 45, 146–148
Almy, Brown, & Slater, 1:101, 147
biographical details, 1:146
carding machine created by, 1:146
first U.S. cotton spinning mill (Pawtucket, Rhode Island), 1:101, 146–147, 148
hydropowered yarn-spinning factories, 1:74, 101, 147
Samuel Slater and Company, 1:147
Slater mill system (also Rhode Island system), 1:61, 74, 101, 146–147, 161
Slaterville, Rhode Island, founded by, 1:5

- water frame spinning machine created by, 1:146
and workforce and labor conditions, 1:147
- Smallpox, eradication of, 3:135–136
- Smallpox inoculation, 1:56–59
primary document: George Washington's order for soldiers to receive inoculation (1778), 1:58
primary document: letter of Edward Rowse to Thomas Jefferson suggesting possibility of vaccines for other diseases (1805), 1:58–59
- Smartphone and 3G network, 3:311–312
- Smith, Adam, 1:138; 2:179, 180
- Smith, Al, 2:51, 239
- Smith, Andrew, 2:77
- Smith, C. Harold, 2:45–46, 186–187
- Smith, Dave (engineer and synthesizer designer), 3:297
- Smith, David M. (modern clothespin patent), 1:196
- Smith, Francis Pettit, 1:293
- Smith, Fred, 2:225
- Smith, Hamilton (genetic researcher), 3:203
- Smith, Hamilton (inventor of rudimentary rotary washing machine), 2:134
- Smith, Horace, 1:281
- Smith, John Lawrence, 1:244
- Smith, Lucien, 2:20
- Smith, Richard, 2:263
- Smith, Roe, 1:131
- Smith, Sam (co-inventor of Scotchgard Fabric Protector), 3:127
- Smith, Samuel (copper tycoon), 2:225
- Smith & Wesson Company, 1:281
- Smithing. *See* Goldsmiths; Iron- and silversmithing
- Smithsonian Institution
gum with bar code at, 3:25
and Henry, Joseph, 1:7, 237–238
original UNIVAC at, 3:151
space shuttles at, 3:238
and Wright brothers, 2:165, 177
- Smoke detector, 3:136–137
primary document: Chris P. Borreson's account of the Iroquois Theater Fire (1904), 1:137
- Snyder (Holberton), Frances "Betty," 3:1, 56
- Soda fountain, 2:140–141
- Solar compass, 1:287. *See also* Equatorial sextant
- Solar energy, 3:235–237
- SONAR, 2:318–319
- Sorensen, Charles Emil, 2:179–180
- Sorensen, Edward M., 3:48
- Space science and technology, 3:137
primary document: account of astronaut David Alexander Wolf voting in space (1997), 3:138
- Space shuttle, 3:96, 237–239
- Spar torpedo, 1:288
- Species extinction, 1:47, 175, 176; 3:250
- Spindler, Michael, 3:178
- Spinning wheel, 1:59–61
primary document: "Address to the Ladies" urging American women to boycott British goods (1767), 1:61
- Spirit of St. Louis*, 2:175, 178, 190
- Spork, 2:141–142
- Sprague, Frank Julian, 2:5, 242
- Sputnik 1, 2:313; 3:2–3, 14, 16, 89–90, 93, 94–95, 126, 284
- Sputnik 2, 3:3, 93, 126
- Standard Oil, 2:2, 233–234
- Stanford, Leland, 1:275, 276, 290
- Stanley, William, Jr., 2:9–10
closed core transformer perfected by, 2:9, 64
and Great Barrington Electrification, 2:9, 62
primary document: AIEE member biography for, 2:10
Stanley Manufacturing Company founded by, 2:9
at Westinghouse Electric Company, 2:9, 64
- Stanley Home Products, 3:157
- Stanley Motor Carriage Company, 1:148
- Stealth technologies, 3:138–140
- Steam engine, 1:148–149
patent of Watt, James, 1:107, 148, 151, 167, 289, 293
- Steam locomotive, 1:288–291
Best Friend steam engine, 1:181
- Steam shovel, 1:291–292
- Steam tractor, 1:149–150
- Steamboat, 1:150–154
primary document: newspaper announcement of Fulton's steamboat (1807), 1:153–154
primary document: Dickens's account of ride on steamboat (1842), 1:154
- Steel arched bridge, 2:142–143
- Stephenson, John, 1:239, 265
- Stethoscope, binaural, 2:143–144
- Stetson. *See* Cowboy hat (Stetson)
- Stevens, Edwin, 1:274, 293–294
- Stevens, John, 1:274, 292–293
- Stevens, Robert Livingston (1787–1856), 1:292–294
biographical details, 1:292–293
first U.S. locomotive built by, 1:293
railroad T-rail designed by, 1:168, 274, 293
steamship and steam ferry designs of, 1:76, 115, 274, 293
- Stewart, Philo Penfield, 1:207–208
- Stockyards, 2:144–145
primary document: photograph of Chicago's Union Stock Yards (1907), 2:145
- Stoddard, Joshua, 1:183–185
- Stone, Edward, 2:18
- Stoneman, George, 1:185
- Stoner, Eugene, 3:83, 84
- Stowe, Harriet Beecher, 1:170
- Strassman, Fritz, 2:260
- Strategic Defense Initiative (SDI), 3:12, 90, 239–240
- Strauss, Joseph, 2:274–276
- Strauss, Levi (1829–1902), 1:294; 2:15, 84–86

- Street lighting, 1:62
- Stuart, Gilbert, 1:10
- Studebaker Corporation, 2:182, 264
- Sturgeon, William, 1:199, 261
- Sturvaden, Clarence, 2:258
- Submarine, 1:154–155
- Submarine technology, 2:319–320
- Subway system of New York City, 2:242–243
- Sullivan, Louis, 2:174
- Sullivan, Thomas, 2:321, 322
- Sullivan, William, 2:176
- Superconductivity, 3:140–141
- Supersonic Pressure Tunnel, 3:73
- Suspension bridge, 1:155–157
- Sustainable agriculture, 3:240–242
- Sutherland, John Buie, 2:3, 125
- Swim fins, 1:62–63
- Swivel chair, 1:157–158
- Szilard, Leo, 2:201, 260, 296
- T-rail. *See* Railroad T-rail and tie
- Taft, Howard, 2:178
- Talbot, William Henry Fox, 2:32, 120
- Talking movies, 2:243–245
- Tampon, 2:320–321
- Tape measure, 2:146
- Tarrant, Robert, 2:114
- Tarter, Jill (1944–), 3:312–313
- Taussig, Helen (1898–1986), 3:141–143
- Taylor, Frederick (1856–1915), 2:146–147, 161, 170, 173
- TCP/IP (Transmission Control Protocol/Internet Protocol), 3:3, 107, 208, 300. *See also* Internet Protocol (IP); Transmission Control Protocol (TCP)
- Tea bag, 2:321–322
- Telegraph, 1:294–297
- Atlantic Telegraph Company, 1:226–227, 302
- invention of, 1:7, 226, 256, 260, 261–262, 236
- and Lincoln, Abraham, 1:257, 296, 310–311
- primary document: act authorizing construction of a transcontinental telegraph (1855), 1:297
- printing telegraph, 1:169, 271–272, 310
- Western Union Telegraph Company, 1:310–311
- Telenet, 3:3
- Telephone, 2:322–325
- first practical telephone credited to Bell, Alexander Graham, 2:5, 26–27, 322–325; 3:329
- mobile phone, 3:218–219
- touch-tone phones, 3:145
- Telephone switching, computerized, 3:143–144
- Television, 2:325–328
- Ten-Hour Movement, 1:297–299
- primary document: excerpt from preamble and constitution of the Lowell Female Labor Reform Association (1846), 1:298–299
- Tennessee Valley Authority Electricity Project (TVA), 2:328–329
- Terry, Eli, 1:74
- Tesla, Nikola (1856–1943), 2:9, 57, 58, 61, 62, 64, 147–149
- AC induction motor patented by, 2:10–12, 148–149
- biographical details, 2:147
- and Niagara Falls Power Plant, 2:107
- primary document: excerpt from commemoration address for Niagara Falls Power Plant, 2:108–112
- Thayer, Nathaniel, 1:178
- Thomas, David, 1:76
- Thomas, Valerie (1943–), 3:144
- Thomas, Vivien Theodore (1910–1985), 2:329–331
- Thomas de Colmar, Charles Xavier, 2:113
- Thompson, Benjamin (Count Rumford) (1753–1814), 1:158–159
- biographical details, 1:98, 158
- coffee percolator invented by, 1:98–99
- Rumford fireplace invented by, 1:141, 158–159
- Thompson, Ken (1943–), 3:313–316
- primary document: interview with Ken Thompson, inventor of UNIX (2011), 3:314–316
- Thompson Ramo Woolridge (TRW), 3:255
- Thoreau, Henry David, 1:46, 168
- Thornton, William, 1:304–305
- 3-D printing, 3:316–317
- as “additive manufacturing” (AM), 3:316
- bioprinting, 3:248, 317
- 3-D technology
- bioprinting, 3:248, 317
- Google Earth, 3:275
- and medicine, 3:250
- 3-D filmmaking, 3:248
- 3-D printing, 3:316–317
- 3-D television, 3:248
- Three-piece iron plow, 1:159–161
- primary document: petition to Congress for renewal of Jethro Wood’s patent (1846), 1:160–161
- Three-wheel clock, 1:63–64
- primary document: James Ferguson’s description of Benjamin Franklin’s three-wheel clock (1773), 1:64
- Tiananmen Square protests, 3:164
- Ticker tape, 2:149
- Tinsmiths, 1:222, 230. *See also* Iron- and silversmithing
- Tizard Mission, 2:331
- Tocqueville, Alexis de, 1:169
- Tom Thumb* locomotive, 1:7, 150, 289; 2:150–152
- primary document: John Latrobe’s description (1830), 2:150–152
- Toothpaste, 1:299–301
- TOR (The Onion Router), 3:318
- Torpedo, 1:301–302
- Torrey, John, 1:78
- Torvalds, Linus (1969–), 3:318–319

- Touch-tone phones, 3:145
- Track-type tractor, 2:152
- Traffic light, electric, 2:245–246
- Trans-Alaska Pipeline, 3:145–147
 - primary document: bill to reform the Trans-Alaska Pipeline System Authorization Act (1989), 3:146–147
- Transatlantic cable, 1:302–303
- Transcendental Movement, 1:168, 170–171
- Transcontinental Railroad, 1:208–209, 258, 275, 288–289, 296; 2:3, 153–155
- Transistor radio, 3:148–149
- Transmission Control Protocol (TCP)
 - creation of, 3:3
 - and early Internet, 3:208
 - and packet switching, 3:17, 107
 - TCP/IP, 3:3, 107, 208, 300
- Transverse shuttle, 1:303
- Tremblay, Bob, 3:24
- Triangle Shirtwaist Factory Fire (1911), 2:5, 285
- Trinity of personal computers, 3:223–224
- Trinity test (first U.S. nuclear test), 2:260, 272, 297, 303
- Triode tube, 2:24
- Truman, Harry S., 2:303; 3:311
 - and bombing of Hiroshima and Nagasaki, 2:260–261
 - and creation of hydrogen bomb, 2:260, 283, 297; 3:89
 - and National Science Foundation, 3:99
- Trump, Donald, 3:278, 295, 323
- Turbine engine, gas powered, 2:247
- Turtle* submarine, 1:17–18, 65–66, 301
 - action in American Revolution, 1:17–18, 65
 - primary document: engraving of American *Turtle* (1775), 1:18
 - primary document: letter from David Bushnell to Thomas Jefferson regarding experiments with submarines (1787), 1:66
- TV dinner, 3:149
- Twain, Mark, 2:1, 2
- Twine knotter, 1:304
- Twine self-binding harvester, 2:155
- Twist drill, 1:304
- Typewriter and QWERTY, 1:271; 2:155–156
 - electric typewriters, 2:173; 3:61–62, 69
 - and industrialization of leisure, 2:5
- Tyson, Neil deGrasse (1958–), 3:319–321
- UAVs. *See* Drones
- Unimate/industrial robot, 3:150
- United States Capitol Building, construction of, 1:304–306
 - design competition for, 1:304–305
 - fire during War of 1812, 1:305
 - rebuilding of, 1:305
 - renovation (2013), 1:305–306
- United States Constitution, 1:4, 25, 304–306
 - commerce clause in, 1:139
 - Constitutional Convention (1776), 1:53
 - Constitutional Convention (1787), 1:26, 112, 136
 - on copyright and patent law, 1:136
 - on monopolies, 1:136
 - Nineteenth Amendment, 1:309
- United States Patent Board, 1:4, 107
- United States Sanitary Commission (USSC), 1:187, 306–307
- Universal Automatic Computer (UNIVAC), 3:1, 150–151
 - and A-0 program, 3:1
 - cost of, 3:151
 - creation of, 3:65, 150–151
 - purpose of, 3:69, 150
 - size of, 3:151
 - sold to U.S. Census Bureau, 3:151, 189
- Unmanned aerial vehicles (UAVs). *See* Drones
- URL, 3:184, 208
- Vaccines, 3:151–153
 - eradication of smallpox, 3:135–136
 - polio vaccine, 3:54, 118–119, 124, 125–126, 152
 - smallpox inoculation, 1:56–59
- Vail, Alfred, 1:7, 169, 260–262, 271–272, 295
- Vapor-compression refrigerator, 1:161
- Varmus, Harold Eliot, 3:261
- Vaughan, Dorothy (1910–2008), 3:153–155
- Vaux, Calvert, 2:6
- Velocipede, 2:156–157
- Venable, James, 1:178
- Vending machine, 1:157–158
- Vibrator, 2:158–159
- Victor Adding Machine Company, 2:114
- Victor Talking Machine Company, 2:29, 209–210, 117
- Victoria, Queen
 - Eads, James B., recipient of Albert Medal of the Royal Society of Arts from, 2:143
 - fan of carpet sweepers, 2:38
 - first official telegraphic exchange from, 1:302
 - phonograph message recorded by, 2:117
- Victorian Era
 - and Central Park (New York City), 2:5–6
 - and Columbian Exposition (1893, Chicago), 2:5–6
 - corsets as erotica in, 1:212
 - decorum in, 2:5–6
 - labor relations in, 2:154
 - time as commodity in, 2:5
 - See also* Industrialism, Reconstruction, and the Gilded Age
- Victrola. *See* Gramophone/Victrola
- Video game, 3:321–323
- Video streaming services, 3:323
- Virtual reality (VR), 3:323–325
- Vocoder, 3:155

- Vogt, Peter K., 3:261
 Voight, Henry, 1:76
 Volwiler, Ernest H., 1:179
 Voyager spacecraft, 3:14, 16, 75, 96, 122, 127, 144, 156
 Vulcanization, 1:307–308
- Wadsworth, Augustus, 3:13
 Wagner, David, 3:32
 Wales, Jimmy, 3:250
 Walker, Mary (1832–1919), 1:308–309
 Waltham-Lowell textile system, 1:5, 61, 74, 128–130, 161–162, 297–298
 Wang, An (1920–1990), 3:325–326
 Washing machine, electric, 2:247–248
 Washington College, 1:253–254
 Washington, George
 almanacs used by, 1:12
 American Philosophical Society member, 1:8
 and American Revolution, 1:18, 116, 138
 and canal building project, 1:6, 95, 106–107
 Census Act (1790) signed by, 1:73
 forgiveness of Greene family's debts, 1:117
 glasses designed for by Franklin, Benjamin, 1:52
 innovation encouraged by, 1:74
 and National Road, 1:76, 132–133
 portraits of by Stuart, Gilbert, 1:10
 primary document: letter from Robert Fulton urging support of canal construction, 1:106–107
 primary document: order for all soldiers to receive smallpox inoculation, 1:58
 Rittenhouse, David, appointed as inaugural director of U.S. Mint by, 1:53
 on Turtle submarine, 1:66
 U.S. Capitol Building project begun by, 1:304–305
 Washington, Martha, 1:39, 101
 Water heater, 2:159–160
 Waterhouse, Benjamin, 1:45, 75
 Watson (computer), 3:191
 Watson, James, 3:5, 202
 Watson, Thomas, 2:26–27, 323; 3:68
 Watt, James, 1:107, 148, 151, 167, 289, 293, 143
 Weather Bureau, 2: 7–8
 Webster, Daniel, 1:233
 Webster, Noah, 1:135, 169
 Wedgwood, Thomas, 2:32
 Weinberg, Alvin M., 2:264–265; 3:104
 Welding, alternating current, 2:248–249
 Welding, automatic, 2:249
 Weller, Thomas H., 3:4
 Wells, Horace, 1:178
 Wells Fargo, 1:172; 3:307
 Welter, Barbara, 1:170
 Wescoff (Meltzer), Marilyn 3:1, 56
 Western Union Telegraph Company, 1:310–311
 Westinghouse, George, 2:3, 36, 160–161
 and gas transmission, 2:73
 and Niagara Falls Power Plant, 2:107–108, 110
 and railroad switch system, 2:127
 and Stanley, William, 2:9, 64
 support for alternating current (AC), 2:58, 62, 107, 148
 Westinghouse air brake, 2:160–161
 Wharton, John C., 2:45
 Wheel cipher, 1:162–163
 primary document: excerpts from Thomas Jefferson's notes on the wheel cipher (undated), 1:163
 White, Canvass, 1:76, 105
 White, Ellen, 1:236
 White, Lydia, 1:201
 “White out,” 3:61–62
 Whitney, Eli (1765–1825), 1:82, 163–166, 204
 cotton gin invented by, 1:5, 61, 86, 99–100, 117, 164
 and development of interchangeable parts, 1:74, 118–119, 131
 and development of milling machine, 1:130, 131, 164–165
 primary document: letter to his father regarding ginning of cotton (1793), 1:165–166
 Whiton, David Erskine (1825–1904), 1:67–68
 Wiley, Harvey, 2:136; 3:18
 Wilkins, Maurice, 3:5
 Willard, Emma, 1:170
 Willard, Simon, 1:87
 Williams, Roberta (1953–) and Ken (1954–), 3:327–328
 Wilson, Allen Benjamin, 1:283
 Wilson, James, 3:203
 Wilson, Joseph C., 3:158
 Wilson, Woodrow, 1:20, 283, 285; 2:163, 172, 223; 3:142
 Wilson Dam, 2:328
 Wind energy, 3:242–244
 Windmill. *See* Metal windmill
 Winthrop, John (1714–1779), 1:68–69
 primary document: observation of the planet Venus (1761), 1:69
 Wireless communication, 3:328–330
 Wise, Brownie (1913–1992), 3:157–158
 Women's Airforce Service Pilots (WASPs), 2:331–332
 authorized and overseen by Arnold, Hap, 2:261, 331–332
 and Avenger Field (World War II WASPs home), 2:261–262
 deactivation of, 2:262, 332
 merging of WAFS and WFTD to form WASP, 2:262, 332
 primary document: letters of Mary Anna Martin Wyall, WASP pilot trainee (1944), 2:262–263
 Women's Auxiliary Ferrying Squadron (WAFS), 2:261–262, 332
 Women's Flying Training Detachment (WFTD), 2:261–262, 332
 Wood, Carl, 3:70

- Wood, Jethro, **1**:160
- Wood, John C., **2**:183
- Woodbury, Robert, **1**:131
- Woodland, Norman, **3**:25–26
- Woodruff, Robert W., **2**:44
- Woodward, John, **2**:284
- World Wide Web. *See* Internet
- World's Columbian Exposition (1893, Chicago), **2**:58, 107, 162, 167
- AC generator and transformer at, **2**:58, 63, 107
- dishwashing machine at, **2**:4, 48–49
- Ferris wheel at, **2**:66, 67–68
- Kinematoscope at, **2**:6, 243
- refracting telescope at, **2**:167
- Rumford Kitchen at, **1**:141–142, 223; **2**:129
- zipper at, **1**:311
- World's Fairs, **1**:218, 224, 253; **2**:5–6, 66, 161–164, 253; **3**:28, 57–58, 145, 155
- female participation in, **2**:4, 193
- history of, **2**:161–164
- IBM pavilion at 1964 World's Fair, **3**:68
- Louisiana Purchase Exposition (1904, St. Louis), **2**:45, 67, 162–163, 187
- Philadelphia Centennial Exposition (1876), **2**:112, 134, 161
- See also* Great Exhibition of 1851 (London); World's Columbian Exposition (1893, Chicago)
- Wozniak, Steve (1950–), **3**:158, 177–180, 209, 223, 244–245
- Wright, Wilbur (1867–1912) and Orville (1871–1948), **2**:164–166, 223
- first powered, controlled aircraft, **2**:7, 164–166, 170–171, 178, 312
- primary document: entry from Orville Wright's diary, **2**:166
- Wu, Chien-Shiung (1912–1997), **2**:333–334
- Wyll, Mary Anna Martin, **2**:262–263
- Xerox Corporation, **3**:132, 158–160, 190, 214–215, 264, 292
- primary document: patent for xerography (1956), **3**:159–160
- Y2K, **3**:169
- Yale, Linus Jr., **1**:216
- Yalow, Rosalyn Sussman (1921–2011), **3**:160–162
- Yerkes, Charles Tyson, **2**:67, 167
- Yerkes Observatory, **2**:166–168
- YouTube, **3**:330
- Zipper, **1**:311

Technical Innovation in American History

Technical Innovation in American History

An Encyclopedia of Science and Technology

VOLUME THREE: THE COLD WAR TO THE PRESENT

ROSANNE WELCH AND PEG A. LAMPHIER, EDITORS



An Imprint of ABC-CLIO, LLC
Santa Barbara, California • Denver, Colorado

Copyright © 2019 by ABC-CLIO, LLC

Every reasonable effort has been made to trace the owners of copyright materials in this book, but in some instances this has proven impossible. The editors and publishers will be glad to receive information leading to more complete acknowledgments in subsequent printings of the book and in the meantime extend their apologies for any omissions.

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, except for the inclusion of brief quotations in a review, without prior permission in writing from the publisher.

Library of Congress Cataloging-in-Publication Data

Names: Welch, Rosanne, author. | Lamphier, Peg A., author.

Title: Technical innovation in American history : an encyclopedia of science and technology / Rosanne Welch and Peg A. Lamphier, editors.

Description: Santa Barbara, California : ABC-CLIO, an Imprint of ABC-CLIO, LLC, 2019. | Includes bibliographical references.

Identifiers: LCCN 2018043489 (print) | LCCN 2018045557 (ebook) | ISBN 9781610690942 (ebook) | ISBN 9781610690935 (set) | ISBN 9781440847219 (volume 1) | ISBN 9781440847226 (volume 2) | ISBN 9781440847233 (volume 3)

Subjects: LCSH: Technological innovations—United States—History—Encyclopedias.

Classification: LCC T21 (ebook) | LCC T21 .T37 2019 (print) | DDC 609.73/03—dc23

LC record available at <https://lcn.loc.gov/2018043489>

ISBN: 978-1-61069-093-5 (set)
978-1-4408-4721-9 (vol. 1)
978-1-4408-4722-6 (vol. 2)
978-1-4408-4723-3 (vol. 3)
978-1-61069-094-2 (ebook)

23 22 21 20 19 1 2 3 4 5

This book is also available as an eBook.

ABC-CLIO

An Imprint of ABC-CLIO, LLC

ABC-CLIO, LLC

147 Castilian Drive

Santa Barbara, California 93117

www.abc-clio.com

This book is printed on acid-free paper 

Manufactured in the United States of America

Contents

VOLUME 1: COLONIAL AMERICA TO 1865

Introduction, xxi

Chronology, xxvii

Section 1: Colonial America and Enlightenment Science, 1

Overview, 1

American Philosophical Society, 8

Primary Document: Memorial of the American Philosophical Society Favoring an Exploration of the Alaskan Coast (1868), 10

Astronomical Almanacs, 11

Primary Document: Aphorisms from *Poor Richard's Almanack* (1732–1758), 13

Banneker, Benjamin (1731–1806), 13

Primary Document: Letter of Thomas Jefferson to Benjamin Banneker, Expressing Jefferson's Belief That Blacks Had Talents Equal to Other Races (1791), 14

Primary Document: Frontispiece of Benjamin Banneker's *Pennsylvania, Delaware, Maryland and Virginia Almanack and Ephemeris* (1792), 15

Bifocals, 16

Primary Document: Benjamin Franklin's Letter Describing His Invention of Bifocals (1725), 17

Bushnell, David (1740–c. 1824), 17

Primary Document: Engraving of David Bushnell's *American Turtle* (1775), 18

Colden, Jane (1724–1766), 19

Daylight Saving Time, 20

Extension Arm (Long Arm), 21

Fire Safety, 21

Flexible Catheter, 22

Food Production, Native American, 23

Franklin, Benjamin (1706–1790), 25

Primary Document: Letter of Benjamin Franklin Describing His Experiments with Electricity (c. 1750), 26

Franklin Stove, 27

Primary Document: Excerpt from Benjamin Franklin's *An Account of the New Invented Pennsylvanian Fire-Places* (1744), 28

Glass Harmonica (Armonica), 30

Primary Document: Excerpt of Benjamin Franklin's Letter to Father Giambatista Beccaria Describing the Glass Harmonica (1762), 32

Glover, Elizabeth (d. 1643), 32

Godfrey, Thomas (1704–1749), 33

Iron- and Silversmithing, 34

Kentucky Long Rifle, 35

Lightning Rod, 36

Primary Document: Frontispiece and Title Page of Benjamin Franklin’s *Experiments and Observations on Electricity* (1774), 37

Loom, 38

Primary Document: Excerpts from the Diary of Martha Ballard Describing Home Weaving (1787), 39

Lucas, Eliza (1722–1793), 40

Primary Document: Letter of Eliza Lucas to Her Father (1741), 41

Masters, Sybilla (c. 1675–1720), 42

Mather, Cotton (1663–1728), 43

Natural History, 44

Onesimus (fl. 1706–1716), 46

Peale, Charles Willson (1741–1827), 47

Primary Document: Letter of Charles Willson Peale to Thomas Jefferson Regarding New Agricultural Inventions and Innovations (1815), 48

Priestley, Joseph (1733–1804), 51

Rittenhouse, David (1732–1796), 52

Primary Document: Letter of Thomas Jefferson to David Rittenhouse (1778), 53

“Saugus Pot,” 54

Schooner, 55

Smallpox Inoculation, 56

Primary Document: George Washington’s Order for All Soldiers to Receive a Smallpox Inoculation (1778) and Letter of Edward Rowse to Thomas Jefferson Suggesting the Possibility of Vaccines for Other Diseases (1805), 58

Spinning Wheel, 59

Primary Document: An “Address to the Ladies” Urging American Women to Boycott British Goods (1767), 61

Street Lighting, 62

Swim Fins, 62

Three-Wheel Clock, 63

Primary Document: James Ferguson’s Description of Benjamin Franklin’s Three-Wheel Clock (1773), 64

Turtle Submarine, 65

Primary Document: Letter of David Bushnell to Thomas Jefferson Regarding Bushnell’s Experiments with Submarines (1787), 66

Whiton, David Erskine (1825–1904), 67

Winthrop, John (1714–1779), 68

Primary Document: John Winthrop Describes His Observation of the Planet Venus (1761), 69

Section 2: The New Republic and the Market Economy (1780–1820), 71

Overview, 71

Amphibious Steam Vehicle, 79

Primary Document: Image of an Amphibious Steam Vehicle (1834), 81

Apple Parers, 82

Primary Document: Apple Parer Patent Document Image (1836), 83

Babbitt, Sarah “Tabitha” (1779–1853), 84

Ballard, Martha (1735–1812), 84

Banjo Clock, 87

Blackwell, Elizabeth (1821–1910), 87

Primary Document: Excerpts from “Address on the Medical Education of Women” by Elizabeth and Emily Blackwell (1863), 89

Burr Truss Bridge, 91

Canals, 92

Canning Factory, 95

Charting the Gulf Stream, 96

Circular Saw, 97

Coffee Percolator, 98

- Cotton Gin, 99
- Cotton Sewing Thread, 101
- Dental Floss, 102
- Diffraction Grating, 103
- Erie Canal, 104
 - Primary Document: Letter of Robert Fulton to George Washington Urging Him to Support the Construction of Canals (1797), 106
- Evans, Oliver (1755–1819), 107
 - Primary Document: Letters from Oliver Evans to Thomas Jefferson (1804, 1808), 108
- Fire Hydrant, 109
 - Primary Document: Account of the Detroit Fire (1805), 110
- Fitch, John (1743–1798), 111
- Flatboat, 112
- Fulton, Robert (1765–1815), 114
- Gas Tungsten Arc Welding, 115
- Greene, Catharine Littlefield (1755–1814), 116
- High-Pressure Steam Engine, 117
- Interchangeable Parts, 118
- Internal Combustion Engine, 119
- Jefferson, Thomas (1743–1826), 121
- Lewis and Clark Expedition (1804–1806), 123
 - Primary Document: Excerpts from the Journal of the Lewis and Clark Expedition (1805, 1806), 126
- Lobster Trap, 127
- Lowell Mill System, 128
 - Primary Document: Description of the Life of a Mill Girl from the Lowell Offering (1845), 129
- Milling Machine, 130
- Morey, Samuel (1762–1843), 131
- Multitubular Boiler, 132
- National Road, 132
- Odometer, 135
- Patent and Copyright Statutes, 135
- Practical Ocean Navigation, 137
- Report on Manufactures* (1791), 138
- River Steamer, 139
- Rumford Fireplace, 141
- Rush, Benjamin (1746–1813), 142
 - Primary Document: Excerpt from the Medical Writings of Benjamin Rush (1805), 144
- Screw-Cutting Lathe, 145
- Slater, Samuel (1768–1835), 146
- Steam Engine, 148
- Steam Tractor, 149
- Steamboat, 150
 - Primary Document: Newspaper Announcement of Robert Fulton’s Steamboat (1807) and Charles Dickens’s Account of His Ride on an American Steamboat (1842), 153
- Submarine, 154
- Suspension Bridge, 155
- Swivel Chair, 157
- Thompson, Benjamin (Count Rumford) (1753–1814), 158
- Three-Piece Iron Plow, 159
 - Primary Document: Petition to Congress Asking for a Renewal of the Patent on Jethro Wood’s Cast-Iron Plow (1846), 160
- Vapor-Compression Refrigerator, 161
- Waltham-Lowell Textile System, 161
- Wheel Cipher, 162
 - Primary Document: Excerpts from Thomas Jefferson’s Notes on the Wheel Cipher (Undated), 163
- Whitney, Eli (1765–1825), 163
 - Primary Document: Letter of Eli Whitney to His Father Regarding the Ginning of Cotton (1793), 165

Section 3: Antebellum Industrialization and the Civil War (1820–1865), 167

Overview, 167

Adhesive Tape, 174

Agassiz, Louis (1807–1873), 175

Primary Document: Excerpt from the Journal of Louis Agassiz Describing a Trip to the United States (1846), 176

Anesthesia, 178

Ball Bearings and Babbitt Metal, 179

Best Friend Steam Engine, 181

Breast Pump, 182

Brown Truss, 182

Burglar Alarm, 183

Calliope (Steam Organ), 183

Cannon, Double-Barrel, 185

Primary Document: Excerpt from the Memoirs of Former Confederate General Edward Porter Alexander on “Artillery Hell” at Antietam (1907), 186

Civil War Medicine (1861–1865), 186

Primary Document: Report of Medical Director Robert Murray on Union Casualties Suffered at the Battle of Shiloh (1862), 188

Civil War Nursing, 190

Primary Document: Clara Barton’s Poem “The Women Who Went to the Field” (1892), 192

Clipper Ship, 194

Primary Document: Excerpts from the Journal of Alexander Van Valen Describing His Journey to California via Clipper Ship (1849), 196

Clothespin, 196

Coal-Mining Technologies, 197

Coil Magnet/Electromagnet, 199

Colgate, William (1783–1857), 200

Colored Female Free Produce Society, 201

Colt, Samuel (1814–1862), 202

Colt Revolver, 203

Columbiad Cannon, 204

Combine Harvester, 205

Compact Iron Stove, 207

Conestoga Wagon, 208

Primary Document: Excerpt from John G. Abbott’s Recollections of Traveling to California by Wagon Train (1852), 210

Corn Sheller, 211

Corset, 211

Coston, Martha (1826–1904), 213

Cowboy Hat (Stetson), 213

Crumpler, Rebecca (1831–1895), 214

Cylinder Pin Tumbler Lock, 216

Dahlgren Gun, 216

Deere, John (1804–1886) and Deere and Company, 217

Dental Chair, 219

Detachable Collar, 219

Dix, Dorothea (1802–1887), 220

Dustpan, 221

Eggbeater, 222

Electric Doorbell, 223

Electric Stove, 223

Electric Street Railway, 223

Elevator Safety Brake, 224

Equatorial Sextant, 225

Field, Cyrus West (1819–1892), 226

Fire Alarm Call Box, 227

Floating Dry Dock (1849), 228

Primary Document: Excerpt from Abraham Lincoln’s Patent Application for the Floating Dry Dock (1849), 229

Gas Well, 230

Gold-Mining Technologies, 231

Goodyear, Charles (1800–1860), 232

- Grain Elevator, 233
- Gridiron for Cooking, 234
- Hand-Cranked Ice Cream Maker, 234
- Health Reform, 235
- Henry, Joseph (1797–1878), 237
- Hoop Skirt, 238
- Horse-Drawn Streetcar, 239
 - Primary Document: Image of a Horse-Drawn Streetcar (c. 1920), 240
- Hospital Transport Service, Women’s Department, 240
- Howe, Elias (1819–1867), 241
- Howe Truss, 242
- Interchangeable Gun Parts, 243
- Inverted Microscope, 244
- Jervis, John B. (1795–1885), 245
- Land Mines, 245
- Long, Crawford Williamson (1815–1878), 246
- Machine/Gatling Gun, 247
- Mason Jar, 249
- Maynard, Edward (1813–1891), 249
- Maynard Carbine, 250
- McCormick, Cyrus (1809–1884), 252
 - Primary Document: Letter of Robert E. Lee to Cyrus McCormick Regarding the Curriculum at Washington College (1865), 253
- Mechanical Reaper, 254
- Merrick, Solymon (1806–1852), 255
- Military Technology (Civil War), 255
- Mitchell, Maria (1818–1889), 258
- Morse, Samuel F. B. (1791–1872), 260
- Morse Code, 261
- National Academy of Sciences (NAS), 262
- Nightingale Plan, 263
- North, Simeon (1765–1852), 264
- Omnibus System, 265
- Papermaking Machine, 266
- Pencil Eraser, 267
- Pepper (and Salt) Shaker, 267
- Perkins, Jacob (1766–1849), 267
- Platform Scale, 268
- Polished Steel Plow, 269
- Printing, 269
- Printing Telegraph, 271
- Pullman, George Mortimer (1831–1897), 273
- Railroad T-Rail and Tie, 273
- Railroads, 274
 - Primary Document: Pacific Railway Act (1862), 276
- Ratchet Wrench, 279
- Relay, 280
- Repeating Rifle, 280
- Roller Skates, 282
- Rotary Hook (for Sewing Machines), 283
- Rucker Ambulance, 283
- Safety Pin, 284
- Sewing Machine, Automated, 284
- Sewing Pattern, 286
- Solar Compass, 287
- Spar Torpedo, 288
- Steam Locomotive, 288
- Steam Shovel, 291
- Stevens, Robert Livingston (1787–1856), 292
- Strauss, Levi (1829–1902), 294
- Telegraph, 294
 - Primary Document: Act Authorizing Construction of a Transcontinental Telegraph (1855), 297
- Ten-Hour Movement, 297
 - Primary Document: Excerpt from the Preamble and Constitution of the Lowell Female Labor Reform Association (1846), 298
- Toothpaste, 299

Torpedo, 301
 Transatlantic Cable, 302
 Transverse Shuttle, 303
 Twine Knotter, 304
 Twist Drill, 304
 United States Capitol Building, Construction of, 304
 U.S. Sanitary Commission (USSC), 306

Vulcanization, 307
 Walker, Mary (1832–1919), 308
 Western Union Telegraph Company, 310
 Zipper, 311
Bibliography: Colonial America to 1865, 313
Index, 317

VOLUME 2: RECONSTRUCTION THROUGH WORLD WAR II

Section 1: The Rise of Industrialism, Reconstruction, and the Gilded Age (1866–1900), 1

Overview, 1

Abbe, Cleveland (1838–1916), 7

AC Generator and Transformer, 9

Primary Document: American Institute of
 Electrical Engineers (AIEE) Member
 Biography for William Stanley (1934), 10

AC Induction Motor, 10

Primary Document: Nikola Tesla's Patent for an
 AC Induction Motor (1896), 11

Adding Machine with Keys, 14

Amalgamated Clothing Workers of America
 (ACWA), 14

American Telephone and Telegraph Company
 (AT&T), 16

Asphalt, 17

Aspirin, 18

Barbed Wire, 19

Primary Document: Excerpts from an Article on
 Joseph F. Glidden and the Barb-Wire
 Industry (1884), 21

Batteries, 23

Bee Smoker, 24

Primary Document: Excerpt on the Use of a Bee
 Smoker from Moses Quinby's *Mysteries of
 Bee-Keeping Explained* (1853), 24

Bell, Alexander Graham (1847–1922), 26

Primary Document: Letter of Alexander Graham
 Bell to His Parents Describing His Idea for
 the Telephone (1874), 27

Berliner, Emile (1851–1929), 29

Brooklyn Bridge, 30

Camera, 31

Can Opener, 33

Carnegie, Andrew (1836–1919), 34

Carnegie Steel Mill, 35

Primary Document: Correspondence of Andrew
 Carnegie and Henry Clay Frick Regarding
 the Homestead Strike (1892), 37

Carpet Sweeper, 38

Carver, George Washington (1861–1943), 38

Primary Document: George Washington Carver
 Addresses Congress (1921), 41

Cash Register, 42

Celluloid, 42

Coca-Cola, 43

Cotton Candy Machine, 45

Crayons, 45

Curling Iron, 47

Diner (Horse-Drawn), 47

Dishwashing Machine, 48

Dow Chemical Company, 49

- du Pont, Pierre (1870–1954), 50
- DuPont Company, 52
- Duprey, Ana Roqué de (1853–1933), 54
- Duryea, Charles (1861–1938) and Frank (1869–1967), 54
- Earmuffs, 55
- Eastman, George (1854–1932), 56
- Eastman Kodak Company, 56
- Edison, Thomas (1847–1931), 57
- Electric Iron, 59
- Electric Lightbulb, 60
- Electricity, War of the Currents, 61
- Electrification, Urban, 63
- Escalator, 65
- Ferris Wheel, 66
 - Primary Document: Telegrams between Luther Rice and George Ferris Following the Successful Test of the Ferris Wheel (1893), 68
- Folding Cabinet Bed, 68
 - Primary Document: Patent for Folding Cabinet Bed (1885), 69
- Food Preservation, 70
- Fountain Pen, 71
- Frasch Process, 72
- Gas Transmission, 73
- General Electric, 74
- Goodrich, B. F. (1841–1888), 75
- Goodyear, Charles, Jr. (1833–1896), 76
- Hallidie, Andrew Smith (1836–1900), 76
- Harvard Computers, 77
 - Primary Document: Undated Photo of the Harvard Computers, 79
- Haynes, Elwood (1857–1925), 79
- Heyl, Henry (1842–1919), 80
- Ice Cream Soda, 81
- Inman, George (1895–1972), 82
- Iron Ship with Revolving Turret, 83
- Ironing Board, 83
- Jeans, 84
- Jockstrap, 86
- Jones, Amanda T. (1835–1914), 86
 - Primary Document: “The Soldier’s Mother” by Amanda T. Jones (1867), 87
- Kellogg, William Keith (1860–1951), 88
- Kelly, William (1811–1888), 89
- Kier, Samuel (1813–1874), 90
- Kinematoscope, 91
- Knight, Margaret (1838–1914), 91
- Lady Stitchers’ Union, 92
- Lawn Mower, Reel-Type, 93
- Lennox, David (1855–1947), 93
- Linotype Machine, 94
- Margarine, 95
- Matchbook Matches, 96
- Matzeliger, Jan Ernst (1852–1889), 96
- Maxim, Hudson (1853–1927), 97
- Metal Detector, 97
- Metal Electrode Weld, 98
- Metal Windmill, 99
- Military Technology (Post–Civil War through World War I), 100
- Motion Picture Camera, 102
- National Consumers League, 104
- National Institutes of Health (NIH), 105
- Niagara Falls Power Plant, 106
 - Primary Document: Excerpt from Nikola Tesla’s Commemoration Address for the Niagara Falls Power Plant (1897), 108

Office Technology (Pre–World War II), 112

Paper Bag, 114

Paper Clip, 114

Phonograph, 115

Primary Document: Roll Call of Companies at
the Phonograph Convention in Chicago
(1890), 119

Photographic Film, 120

Pipe Wrench, 121

Player Piano, 121

Portland Cement Mortar, 122

Punch Card Tabulator, 123

Quadruplex Telegraph, 124

Railroad Refrigerator Car, 125

Railroad Sleeping Car and Pullman Car, 126

Railroad Switch Systems, 127

Richards, Ellen Swallow (1842–1911), 128

Roebing, Emily (1843–1903), 129

Primary Document: Photograph of the Promenade
on the Brooklyn Bridge (1899), 131

Roebing, John (1806–1869), 131

Roll Film, 133

Roller Coaster, 133

Rotary Washing Machine, 134

Rowing Machine, 135

Saccharine, 135

Silo, 137

Skyscraper, 138

Soda Fountain, 140

Spork, 141

Steel Arched Bridge, 142

Stethoscope, Binaural, 143

Stockyards, 144

Primary Document: Photograph of Chicago’s
Union Stock Yards (1907), 145

Tape Measure, 146

Taylor, Frederick (1856–1915), 146

Tesla, Nikola (1856–1943), 147

Ticker Tape, 149

Tom Thumb Locomotive, 150

Primary Document: John Latrobe’s Description
of the *Tom Thumb* Locomotive (1830), 150

Track-Type Tractor, 152

Transcontinental Railroad, 153

Twine Self-Binding Harvester, 155

Typewriter and QWERTY, 155

Velocipede, 156

Vending Machine, 157

Vibrator, 158

Water Heater, 159

Westinghouse Air Brake, 160

World’s Fairs, 161

Wright, Wilbur (1867–1912) and Orville
(1871–1948), 164

Primary Document: Entry from Orville Wright’s
Diary of December 17, 1903, 166

Yerkes Observatory, 166

Section 2: The Progressive Era and the Roaring Twenties (1900–1929), 169

Overview, 169

Aerosol Spray Can, 176

Airplane, 176

Anderson, Mary (1866–1953), 179

Assembly Line, 179

Primary Document: Excerpt from Henry Ford’s
“The First Assembly Line” (1913), 181

Automobile Technologies (Pre–World War II), 181

Bakelite, 183

Band-Aid, 185

Bell Telephone Laboratories, 185

- Binney & Smith Inc., 186
- Birdseye, Clarence (1886–1956), 187
- Blender, 188
- Blodgett, Katherine (1898–1979), 188
- Boeing, William E. (1881–1956), 189
- Bottle-Making Machine, 190
- Bread Slicer and Wrapping Machine, 191
- Bryant, Alice (1862–1942), 192
- Cannon, Annie Jump (1863–1941), 192
- Carothers, Wallace (1896–1937), 194
- Christmas Tree Lights, 194
- Chuck Wagon, 195
- de Forest, Lee (1873–1961), 196
- Dickelman, Elizabeth (dates unknown), 197
- Dickerson, Mary Cynthia (1866–1923), 197
- Drew, Charles (1904–1950), 198
- Ductile Tungsten, 199
- Einstein, Albert (1879–1955), 199
- Empire State Building, 201
- Ford, Henry (1863–1947), 202
- Freon, 204
- Galvin, Paul Vincent (1895–1959), 205
- General Motors (GM), 206
- Gilbreth, Lillian (1878–1972), 208
- Gramophone/Victrola, 208
- Gumball Machine, 210
- Hewitt, Peter C. (1861–1921), 210
- Hoosier Cabinet, 212
- Hydroelectric Power, 212
- Jacob, Mary Phelps (1891–1970), 214
- Kettering, Charles F. (1876–1958), 215
- Lie Detector, 216
- Life Savers Candy, 217
- Marsh, Albert L. (1877–1944), 217
- McKnight, William L. (1887–1978), 218
- Midgley, Thomas (1889–1944), 219
- Morgan, Garrett (1877–1963), 220
- Motorcycle (Pre–World War II), 221
- National Advisory Committee for Aeronautics (NACA), 223
- Noether, Amalie Emmy (1882–1935), 224
- Olds, Ransom Eli (1864–1950), 225
- Panama Canal, 225
- Primary Document: Excerpt from President Theodore Roosevelt’s Message to Congress After Returning from the Canal Zone in Panama (1906), 228
- Pennington, Mary Engle (1872–1952), 232
- Petroleum Industry (Pre–World War II), 233
- Pop-Up Toaster, 234
- Pushpin, 235
- Radio, 236
- Primary Document: “Radio’s Real Uses” by E. E. Free, Science Editor for *The Forum* (1926), 239
- Rocky Mountain Laboratories, 240
- Safety Razor, 240
- Scotch Tape, 241
- Subway System of New York City, 242
- Talking Movies, 243
- Traffic Light, Electric, 245
- Triode Tube, 246
- Turbine Engine, Gas Powered, 247
- Washing Machine, Electric, 247
- Welding, Alternating Current, 248
- Welding, Automatic, 249

Section 3: The Great Depression and World War II (1930–1945), 251

Overview, 251

Alaska Highway, 257

Primary Document: Excerpt from Ruth Gruber’s Study of Highway Routes to Alaska (1941), 259

Atomic Bombs/Nuclear Weapons, 260

Avenger Field, 261

Primary Document: Letters of Mary Anna Martin Wyall, a Pilot Trainee at Avenger Airfield (1944), 262

B-17 Flying Fortress, 263

Big Science, 264

Blood Transfusion, 265

Bradberry, Henrietta (1903–1979), 266

Calutron Girls, 267

Clarke, Edith (1883–1959), 268

Curtiss-Wright Aeronautical Engineering Cadettes, 269

D Rations, 270

Electric Guitar, 270

Fermi, Enrico (1901–1954), 271

FM Radio, 272

Freeze-Dried Food, 273

Garbage Disposal, 273

Gas Mask, 274

Golden Gate Bridge, 274

Primary Document: Letter of Charles Ellis to the *San Francisco Chronicle* Regarding the Golden Gate Bridge (1930), 275

Helicopter, 276

Hoover Dam, 277

Primary Document: President Franklin D. Roosevelt’s Speech at the Dedication of Hoover Dam (1935), 280

Hydrogen Bomb, 283

Hydroponics, 284

International Ladies’ Garment Workers’ Union (ILGWU), 285

Primary Document: “The Uprising of the 20,000,” 286

Interstate Highway System, 287

Primary Document: Excerpt from the Federal-Aid Highway Act (1956), 289

Lamarr, Hedy (1914–2000), 290

Primary Document: Patent for Hedy Lamarr’s Frequency-Hopping System (1942), 292

Lange, Dorothea (1895–1965), 292

Lend-Lease Program (1941–1945), 293

Liberty Ships, 294

M&M’s, 295

M4 Sherman Tank, 295

Manhattan Project, 296

Mead, Margaret (1901–1978), 297

Microwave Oven, 299

Military Technology (World War II), 299

MIT Radiation Laboratory, 301

Neoprene, 302

Oppenheimer, J. Robert (1904–1967), 303

Paul, Les (1915–2009), 304

Penicillin, 306

pH Meter, 307

Photocopier, 307

Pinball and Arcade Games, 308

Plastic Wrap, 309

Radar, 309

Refrigerator, 310

Richter Scale, 311

Rocketry (Pre–Space Age), 311

Rosie the Riveter, 313

Primary Document: Excerpt from Interview with Maria Isabel Solis (2003), 315
 Schwinger, Julian (1918–1994), 316
 Semple, Ellen Churchill (1863–1932), 317
 SONAR, 318
 Submarine Technology, 319
 Tampon, 320
 Tea Bag, 321
 Telephone, 322

Television, 325
 Tennessee Valley Authority Electricity Project (TVA), 328
 Thomas, Vivien Theodore (1910–1985), 329
 Tizard Mission, 331
 Women's Airforce Service Pilots (WASPs), 331
 Wu, Chien-Shiung (1912–1997), 333

Bibliography: Reconstruction through World War II, 335
Index, 339

VOLUME 3: THE COLD WAR TO THE PRESENT

Section 1: The Cold War (1946–1979), 1

Overview, 1
 911 Emergency System, 8
 Agent Orange, 9
 “Air” Athletic Shoes, 11
 Antiballistic Missiles (ABMs), 11
 Antibiotic, 13
 Apollo Project, 14
 ARPANET, 16
 Aspartame, 18
 Association for Women in Mathematics (AWM), 19
 Atari, 20
 Automotive Technologies (Post–World War II), 22
 Baer, Ralph (1922–2014), 24
 Primary Document: Excerpt from Ralph Baer's Four-Page Paper Describing His Plans for Simple Video Games (1966), 25
 Bar Code Scanner, 25
 Benerito, Ruth Rogan (1916–2013), 27
 Biodiesel, 27
 Primary Document: Statement of Anne Steckel, the Vice President of Federal Affairs of the National Biodiesel Board, to the Senate Committee on Environment and Public Works (2016), 29

Birth Control Pill, 31
 Bomb Disposal Robots/Units, 33
 Brill, Yvonne Madalaine Claeys (1924–2013), 34
 Primary Document: Yvonne Brill's Patent for New Jet Propulsion Technology (1974), 35
 Brown, Marie Van Brittan (1922–1999), 35
 Bulletproof Vest/Kevlar, 36
 Carson, Rachel (1907–1964), 36
 Chlorofluorocarbons (CFCs), 38
 Climate Change, 39
 CO₂ Welding, 41
 Commodore 64, 42
 Comsat/Intelsat, 42
Curanderas, 43
 Dark Matter Science, 45
 Dolby Laboratories, 47
 Drones, 48
 Electric Car, 49
 Primary Document: Article from the energy.gov Web Site on Electric Cars (2014), 50
 Enders, John Franklin (1897–1985), 54
 Engelbart, Douglas (1925–2013), 55

- ENIAC and the “ENIAC Girls,” 55
- Fortran, 56
- Fuller, Richard Buckminster (1895–1983), 57
 - Primary Document: Drawing of R. Buckminster Fuller’s Geodesic Dome (c. 1933), 58
- Global Positioning System (GPS), 59
- Goeppert-Mayer, Maria (1906–1972), 60
- Graham, Bette (1924–1980), 61
- Hamilton, Margaret (1936–), 62
- Haynes, Martha Euphemia Lofton (1890–1980), 63
- Hopper, Grace (1906–1992), 65
- Hydraulic Fracturing (“Fracking”), 66
- Hydrogen Energy, 67
- IBM 360 Computer, 68
- In Vitro Fertilization (IVF), 70
- Integrated Circuit, 70
- Intel Corporation, 71
- Jackson, Mary Winston (1921–2005), 72
- Jet Propulsion Laboratory (JPL), 74
- Johnson, Katherine Goble (1918–), 75
- Kilby, Jack (1923–2005), 76
- Kwilek, Stephanie Louise (1923–2014), 77
- Lacks, Henrietta (1920–1951), 78
- Land, Edwin H. (1909–1991), 79
- Lasers, 80
- LED Lights, 81
- Liquefied Natural Gas (LNG) Carrier, 82
- Liskov, Barbara (1939–), 82
- M16 Rifle, 83
- Magnetic Resonance Imaging (MRI), 84
- MASER, 85
- McClintock, Barbara (1902–1992), 86
- Mercury 13, 88
- Military-Industrial Complex, 88
- Minsky, Marvin (1927–2016), 90
- Moog, Robert (1934–2005), 91
- Morgan, Mary Sherman (1921–2004), 92
- Nanotechnology, 93
- Napalm, 94
- National Aeronautics and Space Administration (NASA), 94
 - Primary Document: Letter of President Dwight Eisenhower to Keith Glennan, Retiring Administrator for NASA (1960), 98
- National Science Foundation (NSF), 98
- Noyce, Robert (1927–1990), 99
 - Primary Document: Personal Interview with Robert Noyce for the IEEE History Center (1975), 100
- Nuclear and Radiation Accidents, 102
- Ochoa, Ellen (1958–), 105
- Orshansky, Mollie (1915–2006), 106
- Packet Switching, 107
- Particle Accelerator, 108
 - Primary Document: Press Release Issued by CERN, the European Organization for Nuclear Research (2012), 109
- Pauling, Linus “Carl” (1901–1994), 110
- Permanent Press Fabric, 111
- Petroleum Industry (Post–World War II), 112
- Plasma Arc Welding, 114
- Plastics, 115
- Polaroids, 117
- Polio Vaccine, 118
- Pong*, 119
- Portable Transistor Radio, 120
- Rocket Girls of JPL, 121

- Primary Document: Press Release Announcing Eleanor F. Helin's Naming to the Women in Science and Technology International (WITI) Hall of Fame (1998), 122
- Rogallo, Francis Melvin (1912–2009), 123
- Sabin, Albert B. (1906–1993), 124
- Salk, Jonas (1914–1995), 125
- Satellites and Space Probes, 126
- Sherman, Patsy O'Connell (1930–2008), 127
- Shippingport Atomic Power Station, 128
- Silent Spring* (1962), 129
- Silicon Valley, 130
- Single-Chip Microprocessor, 132
- Skylab, 133
- Skywalker Ranch, 134
- Smallpox, Eradication of, 135
- Smoke Detector, 136
- Primary Document: Chris P. Borreson's Account of the Iroquois Theater Fire (1904), 137
- Space Science and Technology, 137
- Primary Document: Account of Astronaut David Alexander Wolf Voting in Space (1997), 138
- Stealth Technologies, 138
- Superconductivity, 140
- Taussig, Helen (1898–1986), 141
- Telephone Switching, Computerized, 143
- Thomas, Valerie (1943–), 144
- Touch-Tone Phones, 145
- Trans-Alaska Pipeline, 145
- Primary Document: Bill to Reform the Trans-Alaska Pipeline System Authorization Act (1989), 146
- Transistor Radio, 148
- TV Dinner, 149
- Unimate/Industrial Robot, 150
- Universal Automatic Computer (UNIVAC), 150
- Vaccines, 151
- Vaughan, Dorothy (1910–2008), 153
- Vocoder, 155
- Voyager Spacecraft, 156
- Wise, Brownie (1913–1992), 157
- Xerox Corporation, 158
- Primary Document: Patent for Xerography (1956), 159
- Yalow, Rosalyn Sussman (1921–2011), 160
- Section 2: The Post–Cold War Era (1980–1999), 163**
- Overview*, 163
- AIDS Research, 171
- Primary Document: Introduction to the AIDS Archive by Former Surgeon General C. Everett Koop, 173
- Apple, 177
- Apple II, 179
- Artificial Heart, 180
- Artificial Intelligence (AI), 181
- Berners-Lee, Tim (1955–), 184
- Boston Tunnel, 185
- CD and DVD, 186
- CD-ROM, 188
- Computer/Information Technology, 189
- Cray, Seymour (1925–1996), 191
- Dell, Michael “Saul” (1965–), 192
- Digital Photography, 193
- Primary Document: Excerpt from the Patent for Kodak's Digital Camera (1978), 195
- Elion, Gertrude (1918–1999), 195
- Floppy Disk, 197
- Fossey, Dian (1932–1985), 198
- Gates, Bill (1955–), 199

Genetic Engineering, 201
 Gosling, James (1955–), 204
 IBM Personal Computer, 205
 Infant Formula, 206
 Insulin Pump, 207
 Internet, 208
 Jobs, Steve (1955–2011), 209
 Kare, Susan (1954–), 213
 Laser Cataract Surgery Device, 213
 Metcalfe, Robert (1946–), 214
 Microchip, 215
 Microsoft, 217
 Mobile Phone, 218
 Nuclear Energy/Nuclear Power Plants, 219
 Open-Source Software, 221
 Perlman, Radia (1951–), 222
 Personal Computer (PC), 223
 Ride, Sally (1951–2012), 224
 Ritchie, Dennis (1941–2011), 226
 Primary Document: Abstract for “The Development
 of the C Language” by Dennis Ritchie
 (1993), 227
 Robotic Surgery, 229
 Primary Document: Letter from Elizabeth A.
 Kage, Acting District Director of the FDA, to
 Gary S. Guthart, President of Intuitive
 Surgical Inc., on the Regulation of Robotic
 Surgery (2013), 230
 Satellite Radio, 232
 Self-Driving Cars, 233
 SEMATECH, 234
 Solar Energy, 235
 Space Shuttle, 237
 Strategic Defense Initiative (SDI), 239

Sustainable Agriculture, 240
 Wind Energy, 242
 Wozniak, Steve (1950–), 244

Section 3: The New Millennium (2000–Present), 247

Overview, 247
 Airplane Deicer, 254
 Amazon Web Services, 255
 Amazon.com, 256
 Artificial Memories, 258
 Bashen, Janet (1957–), 259
 Birth Control Patch, 260
 Blizzard Entertainment, 260
 Cancer Research, 261
 Cassini Saturn Mission, 262
 Drake Equation, 264
 e-Book and e-Reader, 264
 e-Sports, 267
 Facebook, 268
 Gene Patenting, 270
 Genetically Modified Foods, 271
 Google, 274
 Google Earth, 275
 Grandin, Temple (1947–), 276
 Hawking, Stephen (1942–2018), 277
 Hubble Space Telescope, 278
 Human Genome Project, 279
 Hybrid Vehicles, 281
 Hypertext, 283
 International Space Station, 283
 Intraocular Contact Lens, 285
 iPod, 286

- Java, 287
 - Primary Document: Interview with James Gosling, the Creator of Java (2001), 288
- Jemison, Mae (1956–), 290
- Joystick/Flight Simulator, 291
- Kurzweil, Ray (1948–), 291
- Linux, 292
- Maker Faire, 293
- March for Science, 295
- Mars Rover Series, 295
- MIDI (Musical Instrument Digital Interface), 297
- Moore, Ann (1934–), 298
- MP3, 298
- Negroponte, Nicholas (1943–), 299
- Netscape, 300
- Nye, Bill (1955–), 302
- One Laptop per Child, 302
- PayPal, 303
- PGP Encryption, 303
- Quantum Science, 304
- RFID Labels, 305
- RU-486/Plan B, 307
- Science Friday*, 308
- SETI (Search for Extraterrestrial Intelligence), 308
- Smartphone and 3G Network, 311
- Tarter, Jill (1944–), 312
- Thompson, Ken (1943–), 313
 - Primary Document: Interview with Ken Thompson, Inventor of the UNIX System (2011), 314
- 3-D Printing, 316
- TOR (The Onion Router), 318
- Torvalds, Linus (1969–), 318
- Tyson, Neil deGrasse (1958–), 319
- Video Game, 321
- Video Streaming Services, 323
- Virtual Reality (VR), 323
- Wang, An (1920–1990), 325
- Williams, Roberta (1953–) and Ken (1954–), 327
- Wireless Communication, 328
- YouTube, 330
- Bibliography: The Cold War to the Present*, 331
- Editors and Contributors*, 335
- Index*, 345

1. The Cold War (1946–1979)

OVERVIEW

The years following the end of World War II through 1979 were a time of rapid technological change and scientific discovery in the United States. Many of the innovations of this period had their roots in the World War II war effort, with rapid advancements made in the 30 years afterward.

The end of the war signaled a decline of the old great powers of Europe and the rise of two superpowers: the United States and the Soviet Union (USSR). The political conflict between these two powers (known as the Cold War) resulted in competition that began not only the nuclear arms race but also the Space Race, the exploration of the oceans and the deep interior of Earth, the rise of telecommunications and civilian nuclear power, and greater awareness of the effects that human activities have on the natural world. Scientific and technological developments in a range of fields—agriculture, biomedicine, computer science, ecology, and meteorology, to name just a few—were also directly and indirectly tied to the global conflict and competition that the Cold War entailed.

There is little doubt that science as we know it today was born during this period and that the Cold War expansion of science and technology continues to reverberate throughout contemporary life. What follows is a brief overview of some of the most significant discoveries and advancements of this period and the ways they have changed our world.

The Dawn of Computer Science

The first general-purpose electronic digital computer, the Electronic Numerical Integrator and Computer

(ENIAC), was developed at the University of Pennsylvania during the World War II years to calculate artillery firing tables for the U.S. Army. Its first six programmers—Jean Jennings Bartik, Frances Snyder Holberton, Kathleen McNulty Mauchly Antonelli, Marlyn Wescoff Meltzer, Ruth Lichterman Teitelbaum, and Frances Bilas Spence—were all women mathematics majors specifically recruited for the task. A huge machine weighing 30 tons, ENIAC is believed to have performed more calculations over the 10 years it was in operation than all of humanity had performed until that time.

The development of ENIAC would lead to the UNIVAC I, produced in 1951 by Remington Rand, an early business machines manufacturer. While the military remained a major customer for these \$1 million machines, UNIVAC computers found a place at utilities, insurance companies, and other civilian enterprises. In 1952, mathematician Grace Hopper developed A-0, a program that allowed a computer user to use English-like words instead of numbers to give the UNIVAC instructions, making it even more suitable for business use and forming the basis for future programming languages.

In 1947, physicists John Bardeen and Walter Brattain, working at Bell Telephone Laboratories with supervisor William Shockley, developed the transistor, a much smaller and more reliable means of regulating and transferring electronic signals than the large and fragile glass vacuum tubes that were in use at the time. This invention not only won them the 1956 Nobel Prize for Physics, it revolutionized the electronics industry, making possible not only smaller computers but an entire array of compact devices for both civilian and military use. Transistor radios were one very popular early application in the 1960s and 1970s—those

heavy radio devices that used to sit in large cabinets in living rooms around the country could now be carried in one hand.

In 1961, the Minuteman I, the second generation of intercontinental ballistic missiles (ICBMs) produced by the United States and developed for the purpose of striking cities in the USSR from U.S. soil, used transistorized computers to continuously calculate their position in flight. The military's high standards for its transistors pushed manufacturers to improve quality control, which in turn benefited civilian applications. When Minuteman I units were decommissioned, some universities received these sturdy computers for use by students, recycling military might into tools for the advancement of civilian goals.

Global Communications—The Development of Satellites and the Birth of the Internet

The technological discoveries made in service of the creation of long-range nuclear missiles were also used toward the development and refinement of satellites. Both the United States and USSR were working on satellite programs in the mid-1950s as members of the International Council of Scientific Unions (an organization that promoted scientific cooperation between nations). Yet the U.S. public was shocked by the news of the successful launch of the first satellite, Sputnik I, by the USSR in October 1957. While the purpose of Sputnik was purely scientific—to collect data on the earth's atmosphere—people feared that if the United States were to fall behind the USSR in any capacity, it would put the country at a dangerous political and military disadvantage. This event helped jar the United States into concentrating a great deal of money and expertise on the exploration of space in the coming years.

The value of satellites as commercial communication tools became a subject of great interest to private companies during this period. In 1960, telecommunications company AT&T filed with the Federal Communications Commission (FCC) for permission to launch an experimental communications satellite, with the intention of launching operational ones as soon as possible afterward. The U.S. government was so focused on its competition with the USSR and the military uses of satellites that this event took it by

surprise, but by mid-1961, AT&T was building its own satellite, and the National Aeronautics and Space Administration (NASA) had awarded contracts to electronics manufacturer RCA and Hughes Aircraft Company for two other projects. To regulate these satellites, Congress passed the Communications Satellite Act of 1962, which created the COMSAT Corporation, a publicly funded organization that develops commercial and international satellite communications systems. By 1964, there had been two satellites each from AT&T, RCA, and Hughes put successfully in orbit. Telephone calls and television signals were transmitted via these satellite links, including some of the 1964 Tokyo Olympics. Use of communications satellites grew exponentially in the following years.

Encouraged by the successes of the U.S. military and commercial satellite programs, other government agencies took an interest in satellites for civilian purposes. In September 1966, the U.S. Department of the Interior, NASA, and the U.S. Department of Agriculture embarked on a project to develop an observation satellite to take specialized photographs of the earth, enabling people to study and evaluate the changes caused by both natural processes and human practices. This goal was achieved in July 1972 with the launch of the Earth Resources Technology Satellite (ERTS-1), later renamed Landsat 1. Landsat satellites have been in orbit ever since, continually adding to the digital archive.

The Defense Advanced Research Projects Agency (DARPA) was another government organization created as a result of the shock of Sputnik. Initiated in February 1958, DARPA would also work on satellite technologies for the purposes of reconnaissance and recording weather observations. However, its best-known and farthest-reaching project would start with the use of dedicated land-based telephone lines.

DARPA research played a central role in launching what is now known as the information age, including developing or furthering much of the basis for the Advanced Research Projects Agency Network (ARPANET), a pioneering network for sharing digital resources among geographically separated computers. Its initial demonstration in 1969 led to the Internet, with world-changing consequences that continue to unfold today.

As ARPANET was being developed, DARPA and the U.S. Air Force also funded a groundbreaking computer framework known as the oN-Line System (NLS). Conceived by engineer and inventor Douglas Engelbart and developed with colleagues at the Stanford Research Institute (SRI), the NLS system was the first to feature hypertext links, a mouse, video monitors, information organized by relevance, on-screen windows, presentation programs, and other modern computing concepts. In what became known as “the Mother of All Demos” because it demonstrated such a wide array of revolutionary features, Engelbart unveiled his system in December 1968 to the audience at the Fall Joint Computer Conference in San Francisco, California. Engelbart’s terminal was linked to a large-format video projection system and via telephone lines to a computer 30 miles away in Menlo Park, California, at SRI’s Augmentation Research Center. The audience could see Engelbart manipulate the mouse and watch as members of his team in Menlo Park joined in the presentation. NLS opened pathways toward today’s wide array of information technologies. The NLS was one of the first to be connected to the ARPANET when it debuted in 1969, along with computing research centers at the University of California, Los Angeles; the University of California, Santa Barbara; and the University of Utah School of Computing.

Another seminal moment in the emergence of today’s Internet occurred in 1973, when electrical engineer Robert Kahn at DARPA asked computer scientist Vinton Cerf, then working at Stanford University, to collaborate on a project to develop an efficient, reliable, and robust method of sending data across the ARPANET. Their work resulted in the creation of the Transmission Control Protocol (TCP) and the Internet Protocol (IP), most often seen together as TCP/IP. These protocols remain a mainstay of the Internet’s unseen technical foundation even today. Kahn and Cerf are referred to as the “Fathers of the Internet” for their invention.

The ARPANET continued to expand, growing from 4 nodes to 38 by 1973, each connecting a university or defense-related data center to the network. The operators of ARPANET realized the system they had built could be of great value for commercial and public use, but the businesses of that day with the infrastructure and deep pockets to build such a network

(mainly AT&T and Western Union) were reluctant to take on the task. A group of developers and engineers who had worked for DARPA and associated private firms thus formed their own company, Telenet, which the FCC approved to sell network communication services in 1974, marking the birth of the first Internet Service Provider (ISP). In its FCC application, Telenet proposed building a hybrid system of terrestrial cabling and satellite links. It started offering services in seven cities in August 1975. This jumped rapidly to 16 cities by the end of 1975, 47 by the end of 1976, and 81 by the end of 1977.

The Space Race

By the mid-1950s, the Cold War had become the background upon which everyday life played out in both the United States and the USSR. The Korean War, the growing numbers and power of nuclear weapons, and the differences in political thought and opinion between the two countries had led to a growing feeling of unease. The shock of the USSR launching Sputnik I in 1957 had jarred the United States to its core. Space was considered the next new frontier in the American tradition of exploration, which the Soviets were now impinging upon. Additionally, the missile used to launch Sputnik into space—the R-7 ICBM—seemed capable of delivering a nuclear warhead to U.S. soil, making gathering intelligence about Soviet military activities especially urgent.

The launch of Sputnik I signaled the start of the Space Race. The USSR followed Sputnik I with Sputnik II in November 1957, and then in January 1958, the United States launched its first satellite, Explorer-I. The States then created the National Aeronautics and Space Administration (NASA) in October 1958, a new organization dedicated to the exploration of space.

At the same time, President Dwight D. Eisenhower also created two additional space programs with national security as their primary goal. The U.S. Air Force directed one program that explored the military potential of space. The other, led by the Central Intelligence Agency (CIA), the Air Force, and a new organization called the National Reconnaissance Office, used orbiting satellites to gather intelligence on the Soviet Union and its allies. This program was

code-named Corona; the existence of the National Reconnaissance Office would be kept secret until the mid-1990s.

The next goal would be to launch a human into space; the Soviet cosmonaut Yuri Gagarin was the first person to go into space in April 1961. The following month, U.S. astronaut Alan Shepard became the first American in space. Shortly thereafter, President John F. Kennedy pronounced that the United States would land a man on the moon before the end of the decade. This pledge was fulfilled on July 20, 1969, when U.S. astronaut Neil Armstrong, as part of the Apollo 11 crew, became the first man to walk on the moon's surface. People at home, thanks to the relatively new medium of television, followed along intently in what might be considered the biggest television event of the 20th century. Broadcasting the moon landing was made possible by a special low-light camera developed by Westinghouse, whose original purpose was for jungle surveillance in the Vietnam War; Intelsat satellites and AT&T landlines would be part of the communications links that would broadcast the signal to the world.

By landing on the moon, the United States effectively “won” the Space Race—the Soviets never succeeded in making a moon landing, and interest in lunar landings began to wane after the early 1970s. Additionally, both countries began to see benefit in working cooperatively rather than competitively on space missions; in July 1975, the joint Apollo-Soyuz mission sent three U.S. astronauts in an Apollo spacecraft to dock with two cosmonauts in a Soviet-made Soyuz vehicle. When the commanders officially greeted each other, their handshake in space served to symbolize an improvement in relations between the two countries.

Advances in Biological Science and Medicine

While researchers in the computer science and communications fields were expanding the ability and ease of communicating nationally and globally, another set of scientists were looking inward, deep into the inner workings of not only the human body, but of all life on earth.

Scientists had known about the existence of animal and human cells since the invention of the microscope in the mid-1600s and had theorized about their

structure, purposes, and behavior since the late 1830s, but success in growing strains of specific cells—an important step in the development of safe and effective vaccines as well as certain cancer treatments, and in genetic research—did not find reliable success until the mid-1940s. Prior to this time, there were not many vaccines in existence, and they often relied on either live animals or animal tissue cultures for their raw materials. This made the study of viruses and the development of vaccines against them slow and difficult. Virologist John Enders and his team at Boston's Children's Hospital developed cell culture techniques that allowed scientists to grow large supplies of many viruses in a wide variety of cell types.

This quickly led to vaccines being developed for polio, measles, and mumps. At the time Enders and his team started their work in 1945, only 13 human viral pathogens had been isolated. By 1961, 58 more had been cultured, along with another 300 viruses that infect animals. Millions of people and animals have benefited from the vaccines developed as a result. Enders and colleagues Thomas H. Weller and Frederick C. Robbins were awarded the Nobel Prize in Physiology or Medicine in 1954 for their work. Other scientists would take an even deeper dive, looking for and trying to understand the most basic building blocks of the cell. The era of modern biology would be born with those discoveries.

Back in 1868, a young Swiss physician named Friedrich Miescher was the first person to isolate genetic material from a cell. He called the compound he discovered “nuclein,” now called nucleic acid. This is the “NA” in DNA (deoxyribonucleic acid) and RNA (ribonucleic acid). It would take until 1944 for scientists to understand the connection between nucleic acid and genes, when the American scientist Oswald Avery managed to transfer the ability to cause disease from one strain of bacteria to another. He also found that the previously harmless bacteria could also pass their new disease-causing trait along. What Avery had moved was nucleic acid, and his experiment showed that genes are made of it.

These discoveries set the stage for one of the most significant biological discoveries ever made: in April 1953, the structure of DNA was revealed. DNA is a code, a means of storing biological data in the form of

genes, which are made of chemicals called “amino acids.” The same set of amino acids are encoded by DNA in all life-forms, whether they be single-celled bacteria, plants, animals, or human beings. Figuring out DNA’s structure has allowed it to be studied and manipulated, greatly furthering our understanding of genes and their role in some forms of disease.

In 1962, molecular biologists Francis Crick, James Watson, and Maurice Wilkins shared the Nobel Prize in Physiology or Medicine for this discovery. This advance was also responsible for the birth of biotechnology, a new field in biology. In California in the early 1970s, scientists invented ways to swap bits of DNA from one organism to another. Since all life is made from the same building blocks, it is possible to do this even between different species. These techniques are being used to research cures for genetic diseases and cancer.

The development of life-saving drugs also saw a golden age in the Cold War era. The first true antibiotic, penicillin, was discovered by accident in 1928 by British bacteriologist Alexander Fleming. He noticed that some bacteria he was trying to grow in glass dishes had been contaminated by a mold—penicillin—and that it was killing that bacteria. Ten years would go by, however, until other scientists tried to purify and grow penicillin for the purposes of testing it for possible use as a medicine. The war effort underway in Britain at that time severely curtailed that country’s ability to do both the large-scale growing of the penicillin mold and the testing required to make sure it was safe, so scientists traveled to the United States to ask for help. The Department of Agriculture’s Northern Regional Research Laboratory (NRRL) in Peoria, Illinois, took on the project in 1941. Other government agencies and pharmaceutical companies soon signed on to help once it was realized how valuable a drug like this could be, especially in wartime, when so many wounded soldiers died of bacterial infections. One of the major goals was to have an adequate supply of the drug on hand to treat casualties from the D-Day invasion of Europe on June 6, 1944.

By 1949, the annual production of penicillin in the United States was in the billions of units, and the price had dropped dramatically, making a life-saving medicine both very inexpensive and widely available. The race was then on to discover additional substances that

would have the same effects on a wider range of bacterial illnesses. The 1950s through the 1970s are considered a golden age of antibiotic discovery, with eight additional classes of antibiotics being introduced. Drugs such as streptomycin, tetracycline, chloramphenicol, erythromycin, rifampicin, and vancomycin were added to the antibiotic arsenal during this time. Chloramphenicol would be the first antibiotic to be created entirely in the laboratory during this period, making it very easy and inexpensive to produce.

The discovery and development of antibiotics has been recognized as one of the greatest advances in therapeutic medicine. Additionally, it was also found that some naturally occurring substances could be used against fungal diseases. Microbiologist Elizabeth Lee Hazen and chemist Rachel Fuller Brown at the Division of Laboratories and Research of the New York State Department of Health would discover nystatin, which was effective against fungal infections of the skin, mouth, throat, and intestinal tract. It was introduced for commercial use in 1954.

Nuclear Arms and Development of Civilian Nuclear Power

Scientists first began teasing out the structure of atoms and their properties in the early 1900s. Coupling this with research on radioactive elements, by the late 1930s, scientists discovered that energy—a lot of it—could be produced by splitting atoms. At that time, British and American physicists looking at this discovery saw different uses for the knowledge. Britain, already embroiled in World War II, saw the potential for a bomb first (and worried that the Germans might already be developing such a weapon), while the United States was initially more interested in developing nuclear energy to run power plants and ships. The U.S. entry into World War II in late 1941 changed this priority drastically, with the ultimate result, the United States developing and dropping two nuclear bombs on Japanese cities, ending the war.

The demonstration of the awesome power of these weapons and their implications was not lost on the rest of the world, especially the United States’ biggest rival. The USSR stepped up its efforts to build such a weapon of its own, testing its first one in 1949. This

would lead to other countries developing and testing nuclear weapons throughout the 1950s, and also to much larger, more powerful bombs.

Tensions came to a head in November 1962 when the United States discovered that the USSR had nuclear missile installations in Cuba, only 90 miles from the Florida coast. This very nearly provoked a nuclear war, and although the Soviet Union backed down at the last moment, both sides had been deeply shaken by the standoff.

This event, along with escalating concerns and protests regarding the effects of nuclear testing on human health and the environment, led to an agreement between the United States, the USSR, and Britain to ban nuclear testing in the atmosphere in August 1963. Five years later, the Nuclear Non-Proliferation Treaty was signed, with non-nuclear-weapon countries agreeing never to acquire nuclear weapons, and the nuclear-weapon states agreeing to pursue nuclear disarmament.

Even in the midst of the turmoil over nuclear arms, nuclear technology started to find uses in peacetime applications, mainly in the production of steam power and electricity. The first nuclear reactor to produce electricity came online in 1951. Named the Experimental Breeder Reactor, it was designed and operated by Argonne National Laboratory in Idaho. Two years later, President Eisenhower proposed an “Atoms for Peace” program, which directed the country’s considerable nuclear research efforts toward electricity generation and set the course for nuclear energy development in the United States. Part of the Nuclear Non-Proliferation Treaty agreement stipulated that nuclear-weapon states share their knowledge of peaceful use of such energy with all other signatories to the agreement.

Even peaceful use of such energy was not always met with acceptance, however. Protestors would find success in limiting the growth of nuclear energy, starting with a demonstration in April 1977 at the construction site for what would become the Seabrook (New Hampshire) Nuclear Power Plant. Resulting in one of the largest mass arrests in U.S. history, the Seabrook action initiated a backlash against nuclear power that played a significant role in limiting the construction of reactors across the country. Dangerous accidents, such

as the partial meltdown of the nuclear core at the Three Mile Island reactor in Pennsylvania in March 1979, helped cement resistance to reactor construction.

The Rise of Environmental Activism

Along with the advancement of science and technology also came concern, first from scientists and then the general public, of how those advances affected the natural world around us and how some of it might have detrimental and even catastrophic effects. The worry that revolved around the destructive power of nuclear weapons and toxic effects of radioactive waste from power plants widened to encompass other areas.

One key figure in examining the negative effects of advancements during this period was Rachel Carson, a marine biologist who joined the U.S. Bureau of Fisheries (which later became part of the U.S. Fish and Wildlife Service) in 1935. Her second book about life in the ocean, *The Sea Around Us*, benefited from research that came as a result of data obtained from submarine warfare of World War II. A gifted writer and storyteller, she was able to package this information into an engaging general-interest book that explained the science of the sea. Published in 1951, it became a best seller, won the National Book Award for nonfiction that following year, and enabled her to quit her job and write full time.

Carson then turned her attention to a problem that had concerned her for at least a decade: the widespread and indiscriminate use of chemicals in agriculture and pest control, most notably DDT. A powerful and long-lasting insecticide discovered by Swiss chemist Paul Hermann Muller at the outbreak of World War II (he would win a Nobel Prize in Physiology and Medicine in 1948 for the discovery), DDT was initially used during the second half of World War II to kill the insects that transmitted malaria and typhus to both civilians and troops. DDT then made a jump to commercial use on crops and home gardens.

Carson’s next book, *Silent Spring*, published in 1962, warned of the dangers to all natural systems from the indiscriminate use of such pesticides and questioned the scope and direction of modern science. *Silent Spring* helped transform and broaden the conservation movement of the previous era into a more

comprehensive and informed environmentalism, and is partially credited for the formation of the U.S. Environmental Protection Agency at the end of 1970.

The new environmental activists would be responsible for actions such as protests against the use of Agent Orange during the Vietnam War. Agent Orange was a mix of vegetation-killing chemicals that was sprayed (along with other herbicides) by the millions of gallons onto Vietnamese forests, jungles, and food crops by the U.S. military between 1962 and 1971. The purpose of the spraying was to deny guerrillas places to hide and to reduce the enemy's food supply. It was found to contain the highly toxic chemical dioxin and is believed to have caused cancer, neurological illnesses, and other serious ailments in both American and Vietnamese soldiers and civilians who were exposed to it, along with birth defects in children. Gaining critical momentum 1968 and often occurring hand in hand with protests against the increasingly unpopular war, the spraying of Agent Orange was suspended in 1970, and all spraying stopped the following year.

The Development and Widespread Use of Synthetic Materials

Another technological advance with wide-ranging effects was the rapid expansion of the development and use of synthetic materials. The invention of plastics was born out of the need to produce items that did not involve the use of natural materials such as wood, metal, or stone. Especially during World War II, these materials were scarce, and replacements that were strong, lightweight, and inexpensive to manufacture were of critical importance. Plastics provided those substitutes. Nylon, invented by DuPont organic chemist Wallace Carothers in 1935 as an alternative to silk, was used for items such as parachutes and ropes. Plexiglas was an excellent alternative to glass for aircraft windows. During World War II, plastic production in the United States soared and continued to rise afterward as the economy expanded and demand for consumer goods came with it. Plastics made possible the development of items such as transistors, critical to the development of computers and a wide range of small electronics, during the early Cold War years of the late 1940s and early 1950s.

Plastics are used in almost all items produced today, including cars and trucks, aircraft, household goods, medical equipment, and clothing.

Synthetic rubber made its appearance during the World War II years when the supply of natural rubber from Asia was cut off. Teams of researchers in government, academic, and industrial laboratories moved from development to manufacture of synthetic rubber in the astounding span of only 18 months—a remarkable scientific and engineering achievement. As with plastic, its production continued to rise as the consumer culture took hold.

Today 70 percent of the rubber used in manufacturing is synthetic and is a descendant of this original, general-purpose rubber substitute. Items such as car and truck tires are frequently made with combinations of synthetic rubber and plastics such as nylon. Items of convenience made with plastic began appearing in the late 1940s and early 1950s as well, with the introduction of food containers such as Tupperware and the disposable diaper.

But the negative aspects of plastic use also became evident. That plastic-lined diaper might have been convenient, but once thrown away, it didn't go away, because most plastics don't decompose. Plastic debris in the oceans was first observed in the 1960s, heightening concerns about its effects on the environment. The first recycling mill to accept residential plastics opened in Conshohocken, Pennsylvania, in 1972 in early recognition of this problem. Most plastics are also derived from oil and gas, which is itself a finite resource, and a problem that modern science and technology is just beginning to address.

The next era in advancements would build on the remarkable achievements of this period and refine and add to them, as well as find new ways to deal with unforeseen problems.

Nancy Beach

Further Reading

“Conflicts in Chemistry: The Case of Plastics.” Chemical Heritage Foundation. <https://www.chemheritage.org/the-history-and-future-of-plastics>, accessed August 30, 2018.

“Discovery and Development of Penicillin.” American Chemical Society. <https://www.acs.org/content>

- /acs/en/education/whatischemistry/landmarks/flemingpenicillin.html, accessed August 30, 2018.
- “Elizabeth Lee Hazen and Rachel Fuller Brown.” Science History Institute. <https://www.sciencehistory.org/historical-profile/elizabeth-lee-hazen-and-rachel-fuller-brown>, accessed September 24, 2018.
- Environmental Protection Agency. <https://www.epa.gov/>, accessed August 30, 2018.
- “50 Years of NASA-Derived Technologies (1958–2008)—NASA Spinoff.” NASA.gov. <https://spinoff.nasa.gov/Spinoff2008/pdf/spinoff2008.pdf>, accessed August 30, 2018.
- Haberman, Clyde. 2014. “Agent Orange’s Long Legacy, for Vietnam and Veterans.” *New York Times*, May 12. https://www.nytimes.com/2014/05/12/us/agent-oranges-long-legacy-for-vietnam-and-veterans.html?_r=0, accessed August 30, 2018.
- “John Enders, MD.” Scienceheroes.com. http://www.scienceheroes.com/index.php?option=com_content&view=article&id=69&Itemid=117, accessed August 30, 2018.
- “The Life and Legacy of Rachel Carson.” <http://www.rachelcarson.org/Default.aspx>, accessed August 30, 2018.
- Mathison, S. L., L. G. Roberts, and P. M. Walker. 2012. “The History of Telenet and the Commercialization of Packet Switching in the U.S.” *IEEE Communications Magazine* 50, no. 5 (May). <http://ieeexplore.ieee.org/document/6194380/>, accessed August 30, 2018.
- “NASA History.” <https://history.nasa.gov/>, accessed August 30, 2018.
- Oreskes, N., and John Krige, eds. 2004. *Science and Technology in the Global Cold War*. Cambridge, MA: MIT Press.
- “Programming the ENIAC.” Columbia University Computing History. <http://www.columbia.edu/cu/computinghistory/eniac.html>, accessed August 30, 2018.
- “The Space Race.” History.com. <http://www.history.com/topics/space-race>, accessed August 30, 2018.
- “Timeline of Computer History.” Computing History Museum. <http://www.computerhistory.org/timeline/1961/>, accessed August 30, 2018.
- “The Transistor in a Century of Electronics.” The Official Web Site of the Nobel Prize. <https://www.nobelprize.org/educational/physics/transistor/history/> (link no longer active), accessed September 24, 2018.
- “U.S. Synthetic Rubber Program.” American Chemical Society. <https://www.acs.org/content/acs/en/education/whatischemistry/landmarks/syntheticrubber.html>, accessed August 30, 2018.
- “Where the Future Becomes Now.” Defense Advanced Research Projects Agency (DARPA). <http://www.darpa.mil/about-us/darpa-history-and-timeline>, accessed September 24, 2018.
- World Nuclear Association. <http://www.world-nuclear.org>, accessed August 30, 2018.

911 Emergency System

The three digit telephone number 911 was the emergency number designated by the United States in 1968. It provides the public with quick and easy access to a public safety answering point (PSAP). Over 95 percent of the United States has access to the Enhanced 911 system (E911), which automatically provides an emergency responder with the caller’s closest address. This number is intended for emergency use only, and attempting to use it for any other purpose, such as a prank call, is considered a crime.

Before the invention of the rotary dial telephone, which gave callers the ability to manually dial a phone number, the use of an operator was required to make a call. In an emergency situation, the caller would have to wait for an operator to pick up and describe the dilemma, and the operator then had to connect the call manually via switchboard. The United Kingdom pioneered the idea of a national emergency number in 1937 using the number 999.

In the United States, the idea for the 911 service originated from the National Association of Fire Chiefs in 1957, when it recommended a single service number for reporting fire-related emergencies. In 1967, the President’s Commission on Law Enforcement and Administration of Justice recommended a single contact for emergency situations be used nationwide. In 1967, the Federal Communications Commission met with American Telephone and Telegraph Company (AT&T) to choose a number, and 911 became the national emergency number in 1968. It

was chosen because it was easy to remember and dial, and it worked well with current phone systems. Although 911 was the national number for emergencies, it did not become widely recognized or available until as late as the 1980s. Canada also uses a 911 system, as do many Caribbean nations.

The system used today is significantly more sophisticated than the original system. Enhanced 911 (E911) provides the emergency dispatcher with the caller's location and is available in over 95 percent of the United States. Using the database function called automatic location identification (ALI), emergency operators can obtain a caller's telephone number and location. The information is gathered by mapping the caller's phone number to a nearby address database. Mobile phones can also provide an emergency operator with location information. This is obtained through radiolocation through a cell tower or through a Global Positioning System within the caller's mobile phone.

The funding for 911 comes from local households and businesses. This appears as a nominal fee on the caller's phone bill, and there is no per-call charge for 911. The caller may be charged for ambulances dispatched through 911 or Enhanced 911; however, this is not a 911 expense but a separate bill.

Thomas A. Newton

See also *Vol. 2, Sec. 1: American Telephone and Telegraph Company (AT&T); Vol. 2, Sec. 3: Telephone*

Further Reading

Burau, Caroline. 2007. *Answering 911: Life in the Hot Seat*. Nepean, Ontario: Borealis Books.

Reagan, Ancel. 2017. *What's Your Emergency?* St. Paul: Minnesota Historical Society Press.

Agent Orange

Agent Orange is a blend of herbicides and defoliants sprayed by U.S. military forces in the Korean and Vietnamese conflicts. Questions about the long-term health effects caused by exposure to the agent, including an increased risk of cancer, ended its legal use.

The first use of tactical herbicides in warfare began in the early 1950s, when British forces employed

massive amounts of defoliants to destroy the insurgents' food crops during the Malayan Emergency. In 1961, the South Vietnamese president Ngo Dinh Diem asked the White House to start an aerial herbicide campaign in his country in an effort to deprive Vietcong fighters of their cover. In November of that year, President John F. Kennedy authorized the start of Operation Ranch Hand, an herbicidal warfare program during which the rural areas of South Vietnam, Laos, and Cambodia were sprayed with 20 million U.S. gallons (76,000 m³) of Agent Orange. The U.S. Air Force used specially refitted Fairchild C-123 Providers that used the call sign "Hades." The herbicide was also used to defoliate the perimeters of military bases and in ships and boats that operated until at least May 1975.

Named by the orange-striped, 55-gallon drums in which it was originally shipped, Agent Orange was manufactured by nine wartime government contractors, although the vast majority of it was produced by the former Monsanto Company and Dow Chemical. It was a combination of equal amounts of two active ingredients: 2,4-dichlorophenoxyacetic acid (2,4-D) and 2,4,5-trichlorophenoxyacetic acid (2,4,5-T). The latter one contained traces of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) as an unwanted byproduct of the chemical reactions.

Hundreds of thousands of U.S. soldiers and nearly 4 million Vietnamese citizens were exposed to Agent Orange during the Vietnam War and in subsequent operations. In 1994, several aircraft used during the Vietnam War were still heavily contaminated. The chemical substance was sprayed from boats, trucks, airplanes, helicopters, and even on foot by soldiers with backpack sprayers. Exposure occurred by breathing the chemical, ingesting food or drink that were contaminated by it, or even by skin and eye contact.

Numerous studies have evaluated the toxicity and the detrimental health effects linked to Agent Orange and its dioxin byproducts. 2,3,7,8-TCDD is, in fact, the most dangerous of all polychlorinated dibenzodioxins (PCDDs or dioxins) and can be highly toxic and teratogenic even in minute doses. TCDD has been classified as a known human carcinogen by several national and international agencies, including the International Agency for Research on Cancer (IARC), the U.S. Environmental Protection Agency (EPA), and



A C-123 aircraft sprays the chemical herbicide and defoliant Agent Orange across a field near Saigon, Vietnam, in 1970. During the Vietnam War, the U.S. Air Force sprayed Agent Orange to clear jungles that provided enemy cover. (Dick Swanson/The LIFE Images Collection/Getty Images)

the U.S. National Toxicology Program (NTP). Agent Orange was sprayed on 3.1 million hectares (12,000 square miles) of jungle, nearly 20 percent of the total forested area of Vietnam, exerting a heavy toll on the local ecological balance. Persistent dioxin contamination settled in the soil and water and entered the food chain, and terrain erosion caused by the loss of trees negatively impacted local ecosystems. Agent Orange was also used or tested by other governments, such as the Republic of Korea in 1960 and the Philippines in 1969.

In 1972, the U.S. Air Force started an operation to remove all remaining Agent Orange barrels from Vietnam, called Operation Pacer IVY. A total of that 1.8 million gallons of the herbicide were collected and stocked on Johnston Atoll, while another 480,000

gallons were stored at Gulfport, Mississippi. From July to September 1977, the herbicides were safely disposed of through incineration in special conditions on board the Dutch ship MT *Vulcanus* during Operation Pacer HO.

Claudio Buttice

See also Chlorofluorocarbons (CFCs); Military-Industrial Complex

Further Reading

American Cancer Society. "Agent Orange and Cancer." www.cancer.org.

Martini, Edwin A. 2012. *Agent Orange: History, Science, and the Politics of Uncertainty*. Amherst: University of Massachusetts Press.

“Air” Athletic Shoes

Invented by a NASA aeronautical engineer, Marion Frank Rudy, “air” athletic shoes were designed using the same technology that made helmets for astronauts. Rudy patented his cushioning system in 1979 that is based on inert gas encapsulated in polyurethane plastics. His work was then trademarked by Nike as the “air” sole. This is one of the many examples of spin-offs of NASA technologies and their impact on society.

NASA spin-offs are “invented to describe specific technologies developed by NASA for its missions that are transferred for commercial use or some other beneficial application.” In the 1970s, NASA and Nike crossed paths. Almost all inventions at the time seemed to trace back to the Apollo missions. The Nike Air Tailwind was released in 1978 with the new rubber-molding technology. The technology allowed Rudy to design a hollowed-out midsole in which he imbedded polyurethane pouches filled with dense gases.

The company marketed the shoes on the assumption that “running on air” would provide the best support and cushioning. The other added benefit was the sacs of gas within the design, which would not wear out even after repeated use. Due to these assumptions, Nike Air was marketed only to elite runners. In the 1980s, Nike discovered that consumers would pay \$100 or more for a pair of “air” athletic shoes.

Nike continued to develop the air shoe technology, which became a defining brand for it, especially when it came to establishing superiority in technology-driven design. Nike became a billion-dollar company in 1986 when it also released its new design of air shoes called the Air Max. This design involved a window in the sole of the shoe that made the air visible to consumers. Besides simply seeing the air, consumers could also poke the gas packet and feel the bounce.

This technology and design evoked excitement among shoe buyers in the 1980s and 1990s because sneakers had become personal gadgets that made consumers feel more like professional athletes. Nike also stressed technology that made the sneakers look futuristic. The Nike Air design was revamped many times with various configurations and locations of the

visible air. However, in the 1990s, studies found that athletes performed better when they trained barefoot. This completely changed Nike’s strategy to investment in a super-flexible shoe with minimal cushioning and maximum flexibility.

Research has also shown that too little cushioning can also be harmful, creating a backlash against the barefoot running fad. Some athletes are moving back to traditional cushioned shoes.

Regardless of shoe preference, few consumers know that the most popular sneaker trend of the late 20th century was based on NASA technology. Other NASA spin-offs include improved infant formula, virtual reality technology, memory foam, satellite television, invisible braces, scratch-proof eyeglass lenses, home water-filtration systems, and cordless tools.

Nicole Curtis-Brown

See also National Aeronautics and Space Administration (NASA); *Vol. 3, Sec. 2: Infant Formula*; *Space Shuttle*; *Vol. 3, Sec. 3: Virtual Reality (VR)*

Further Reading

National Aeronautics and Space Administration. 2013. *Spinoff 2008: Fifty Years of NASA-Derived Technologies*. CreateSpace.

Antiballistic Missiles (ABMs)

A ballistic missile is a missile that is powered and aimed to hit a specific target. Antiballistic missiles (ABM) are a military defense strategy using air missiles to counterattack ballistic missiles while they are still in flight. The ABM knows where to hit the missile by intercepting its target based on its ballistic trajectory—where the missile will go down due to gravity. Ballistic missiles can carry nuclear, chemical, or biological substances, making ABMs an important defense strategy. Though there are many different types of missiles, the antiballistic missile was and still is specifically airborne.

In the 1940s, United States, Germany, and the Soviet Union were working on ABM technology. German V-1 and V-2 programs worked to develop “flying bombs,” some of which were intended to destroy

incoming missiles. At the same time, in the United States, Bell Labs determined that the technology needed to hit a flying missile did not exist.

At the end of World War II in 1945, the U.S. Department of Defense began significant research into ABMs. Improved computing systems in the 1950s made ABMs seem more possible. Early ABM systems proved so expensive that the American defense department determined that it would be cheaper and just as effective to build more nuclear weapons, thus preventing a Soviet nuclear strike through the principle of “mutually assured destruction.” In 1957, the LIM-49 Nike Zeus first went into development. The Zeus became designated a national priority in 1958. In 1962, Zeus testing proved that the ABM could successfully hit targets. Nonetheless, the Zeus was never mass-produced, in part because the proliferation of intercontinental ballistic missiles (ICBMs) made intercepting all of them an impossibility.

The answer to that problem came with the Anti-Ballistic Missile Treaty of 1972, which limited how many missiles the United States and the Soviet Union could build. The treaty also prohibited and permitted what both of the countries were able to do and not do, ranging from developing, testing, and deploying, to both countries having to make amendments, as well as addressing any issues that might oppose compliance to the treaty. Additionally, with the treaty, the two nations were obligated not to deploy ABM missiles, and both parties had to discuss any new invention that replaced anything related to antiballistic missiles. Another name for the Anti-Ballistic Missile Treaty of 1972 was the Strategic Arms Limitation Talks (SALT) Treaty. In May 1972, U.S. president Richard Nixon and Soviet general Leonid Brezhnev had signed the agreement to limit the number of nuclear missiles in both countries’ arsenals.

In 1974, President Richard Nixon inaugurated the Strategic Defense Initiative (SDI), famously known as “Star Wars.” The Strategic Defense Initiative conducted research and experiments to find ways to intercept the intercontinental ballistic missiles (ICBMs) and submarine-launched ballistic missiles (SLBMs) as well. The Star Wars program was immensely controversial because parts of it were secret; it threatened to destabilize the SALT Treaty and threatened to

restart the arms race. As a result, the budget for the program was significantly decreased until President George W. Bush attempted to revive it.

In the 1980s, the Brilliant Pebbles became the centerpiece of the Bush administration’s Strategic Defense Initiative. Satellite-based nonnuclear tungsten projectiles, working in concert with the Brilliant Eyes sensing system, were meant to act as a space-centered ABM system. The Defense Department spent millions on the program and then canceled it in 1994. Nonetheless, the sensor systems developed in the program played an important role in 21st-century missile defense.

The United States withdrew from the Anti-Ballistic Missile Treaty in 2002. Its government argued that missiles from so-called rogue states made ABM technology too important to limit in any way. The day after the United States dropped out of the treaty, Russia dropped out of the Strategic Arms Reduction Treaty.

The Terminal High Altitude Area Defense (THAAD) is a military defense system and uses antiballistic missiles to shoot down any ballistic missile of any range. First funded by the U.S. Army, Lockheed Martin took over the program as the primary contractor in 2008. This defense system was officially deployed in 2012 and is currently installed in the United Arab Emirates, Turkey, and South Korea.

American ABM deployment continues to play an important part in national defense. In 2004, the U.S. Army announced plans to develop ABM systems that would replace seven systems currently in use. New ABM systems aim to shoot down short-, medium-, and intermediate-range missiles. On March 7, 2017, the United States deployed two antiballistic missiles as way to threaten North Korea after it first fired four ballistic missiles into the ocean near Japan.

Jennifer Kyoko Nguyen

See also National Aeronautics and Space Administration (NASA); *Vol. 3, Sec. 2: Space Shuttle*; Strategic Defense Initiative (SDI)

Further Reading

Bruce, Elton C. 1997. *National Missile Defense and the Anti-Ballistic Treaty*. Carlisle Barracks PA: U.S. Army War College.

Glaser, Charles L., and Steve Fetter. 2001. “National Missile Defense and the Future of U.S. Nuclear Weapons Policy.” *International Security* 26, no. 1: 40.

U.S. Government, U.S. Military, and Department of Defense. 2017. *Hitting a Bullet with a Bullet: A History of Ballistic Missile Defense (BMD)*. Independently Published.

Antibiotic

In 1950, the biochemist Rachel Fuller Brown and the microbiologist Elizabeth Hazen codiscovered nystatin, the first antibiotic drug that could effectively treat fungal diseases in humans. Brown and Hazen donated all the profits of nystatin, which is still widely used today, to philanthropic and scientific research. The over \$13 million earned with their breakthrough discovery’s royalties helped many other young women to follow in their footsteps.

Elizabeth Lee Hazen was born in Rich, Mississippi, on August 24, 1885. Orphaned at the age of four, she and her two siblings were adopted by their father’s brother. They all lived in poverty, but her zealous devotion to reading and studying allowed her to excel in academic results. In 1905, she enrolled at the Mississippi University for Women, obtaining a bachelor of science degree in 1910. Up until 1916, she taught physics and biology at Central High School in Jackson, Mississippi, while attending summer study at the University of Tennessee and the University of Virginia. Later she moved to New York City to attend Columbia University, where she was one of the first female students to obtain a master’s in biology there, which she did in 1917, and a PhD in microbiology in 1927.

During World War I, she served in the army as a diagnostic laboratory technician at Camp Sheridan, Alabama, and Camp Mills, New York. In 1931, Hazen started working with the New York State Department of Health, where she was put in charge of the Bacterial Diagnosis Laboratory in Albany, New York. While there, she traced an outbreak of lethal anthrax, located sources of tularemia, and reported the first case in the United States of *Clostridium botulinum*, a source of food poisoning from improperly preserved foods. Hazen also studied in Rhoda W. Benham’s

(1895–1957) mycology laboratory, where she learned a lot about fungi and fungal diseases. After discovering that the fungus *Microsporium audouinii* was responsible for hair loss in school-age children, in 1944, she started producing her own culture collection that later became a state-approved laboratory that helped physicians across the country to identify pathogenic fungi. In the same year, Augustus Wadsworth (1872–1954), founder and head of the division, chose her to lead an investigation into the relationship between fungi and other microbes such as bacteria. After penicillin was discovered in 1928, in fact, many patients treated with the new drug subsequently developed fungal infections in the mouth, skin, and feet as a side effect. Since the team aimed at developing a new substance with antifungal properties, an expert biochemist was needed, and Rachel Fuller Brown was chosen.

Rachel Fuller Brown was born on November 23, 1898, in Springfield, Massachusetts, but she moved to Missouri with her family shortly afterward. During her childhood, Brown always tried to avoid science classes but was fascinated with insects, which she began to collect. In 1912, her father, a real estate agent, left the family, leaving them destitute and forcing her, her mother, and her younger brother to move back to Springfield. Once there, Brown attended Central High School, trying to avoid studying chemistry or physics. Although her mother was too poor to pay for a higher-education degree, Brown’s excellent grades and determination impressed Henrietta F. Dexter, a wealthy friend of her grandmother, who decided to pay for Brown’s tuition at Mount Holyoke College, a college for women in South Hadley, Massachusetts. Brown initially chose to major in history, but after taking chemistry as a compulsory science subject, she graduated with a double major in history and chemistry in 1920.

In 1921, she took a master’s degree in organic chemistry at the University of Chicago. After working as a science teacher in a local girls’ school for three more years, in 1924, Brown returned to the University of Chicago to take a PhD in chemistry and bacteriology. Although she completed her doctorate in just two years, an unexplained delay in arranging her oral examinations prevented her from completing her degree. Since she had no money left, Brown had to

leave Chicago to accept work as an assistant chemist in the research department of the New York State Department of Health. Here, Brown focused her studies on identifying the types of bacteria that caused pneumonia, a disease for which she helped develop a vaccine still used today. She completed the last step for her PhD only several years later. After repaying the educational grants from which she had benefited, her new lifelong objective became helping the poorest youths across the country receive a proper education.

In 1948, Hazen and Brown started working on a new antibiotic to fight fungal infections. Hazen gathered many soil samples from all over the country, where she cultured various bacteria with antifungal properties such as *Actinomyces*. Whenever she found a substance that was effective in killing two strains of pathogenic fungi, *Candida albicans* and *Cryptococcus neoformans*, she sent it to Brown, who isolated the active compound and purified it. After many years of testing, Hazen found a promising bacterium in the soil of William Nourse's dairy farm in Virginia. She named it *Streptomyces noursei* and sent it to Brown, who purified an active compound that was effective against several strains of fungi. After testing its safety in animal experiments, in 1950, the two scientists announced their breakthrough discovery of nystatin, a substance named in honor of the New York State Department of Public Health. In 1954, the pharmaceutical company E. R. Squibb bought it and started mass-scale production of the drug.

All nystatin's patent royalties were assigned by Brown and Hazen to the Research Corporation of New York and the Brown-Hazen Fund. From 1957 to 1978, the fund supported training, research, and other programs to encourage women to take up careers in the biomedical sciences. In May 1975, the two women were the first to receive the Chemical Pioneer Award of the American Institute of Chemists. Brown died at the age of 81 on January 14, 1980, in Albany. Hazen died of acute cardiac arrhythmia on June 24, 1975, in a nursing home in Seattle.

Claudio Buttice

See also Birth Control Pill; Vaccines; *Vol. 3, Sec. 2:* Artificial Heart

Further Reading

- Baldwin, Richard S. 1981. *The Fungus Fighters: Two Women Scientists and Their Discovery*. Ithaca, NY: Cornell University Press.
- Yost, Edna. 1984. *Women of Modern Science*. Westport, CT: Greenwood Press.

Apollo Project

The ultimate mission of the Apollo Project was to land an American on the moon by the end of the 1960s. By the late 1950s, the Soviets had developed superior space technologies. Analysts feared that this Soviet achievement might convince other nations that the Soviet Union was the most advanced and most powerful nation in the world. President John F. Kennedy (1961–1963) sought to counter that by intensifying the U.S.-Soviet space race.

In terms of the percentage of the national budget, the Apollo Project was the largest single scientific program ever undertaken by the United States. Even though some critics raised concerns over the high price tag of the project and safety issues, most Americans supported the idea of outdoing the Soviets through American technological innovation. In spite of the political origins of the Apollo Project, its success made it the highest technological achievement of mankind, which spawned other space ventures including the manned Space Shuttle program and the unmanned Voyager spacecraft.

In 1957, the Soviet Sputnik I satellite was the first man-made object to successfully orbit the earth. To many people, this Soviet achievement signaled Soviet technological superiority. It also implied the superiority of the Soviet Communist system, which had produced it. During the Cold War (1945–1989), a period when the Soviet Union and the United States were competing for world dominance, Soviet space successes might have led to greater world support for the Soviet agenda.

Shortly after taking office in 1961, President Kennedy made the Space Race an American priority. Kennedy believed that the United States had superior economic and technological resources that would allow it to catch up to Soviet achievements and eventually surpass them. Kennedy chose a goal that was not too far in the future that could cause people to lose

interest, but also not too close in the future, which could render it impossible. He stated: “I believe that this nation should commit itself to achieving the goal, before the decade is out, of landing a man on the moon and returning him safely to the Earth.”

According to National Aeronautics and Space Administration (NASA) reports, the cost of the Apollo Project was \$20 billion, which was more than 2 percent of the entire U.S. budget in the 1960s. Critics charged that the money should be spent in other ways, such as to address urgent human problems (including health issues, food shortages, and homelessness). They also questioned the ethics of sending humans on dangerous space missions. Some critics argued that the Apollo Project was a mistake, because unmanned space exploration was much cheaper and safer. However, NASA had more than enough volunteers willing to take the inherent risks, and many Americans supported the project.

The plan was to use a Saturn V rocket to boost the Apollo spacecraft out of the earth’s gravitational pull. Once in space, the rocket would then fire a second time and send the spacecraft darting to the moon. The spacecraft was designed with three major compartments: a command module (which housed the astronauts and navigation instruments), a service module (which carried water, oxygen, and fuel), and a lunar model designed to transport two astronauts to and from the moon’s surface while a third crewman remained in the command module.

The Apollo Project began with a series of tests. After more than 12 unmanned suborbital and orbital flights between 1961 and 1966, the project team decided that the craft was ready for a human crew. Apollo 1 was a disaster. On January 27, 1967, the craft exploded, and the three crew members died in the fire. NASA scientists suspended the Apollo Project for more than a year to redesign the craft in an effort to increase crew safety. NASA then conducted tests with the next five unmanned missions, Apollo 2 through Apollo 6. Apollo 7, the first manned mission since the Apollo 1 tragedy, was launched on October 11, 1968. For 10 days and 20 hours, the crew orbited the earth and then returned safely. Launched on December 21, 1968, Apollo 8 orbited the moon during Christmas day and then returned safely to earth. Both Apollo 9 (March 3, 1969) and Apollo 10 (May 18, 1969) orbited

the moon and practiced lunar and command module docking before returning to earth.

On July 16, 1969, Neil A. Armstrong, Edwin “Buzz” Aldrin, and Michael Collins embarked on the historic eight-day Apollo 11 mission. While Collins remained in *Columbia*, the command module, orbiting the moon, Armstrong and Aldrin piloted *Eagle* (the lunar module) and landed on the moon’s Sea of Tranquility. Upon landing, they reported to Earth, “Houston, Tranquility Base here. The *Eagle* has landed.” Armstrong was the first human to set foot on the moon. The moment he achieved this major milestone, he stated, “That’s one small step for man; one giant leap for mankind.”

The world watched the successful mission broadcasted live on television. Aldrin joined Armstrong on the surface of the moon, and the two men conducted various experiments, planted a U.S. flag, and deployed a laser beam reflector. Since that time, the reflector has been used by scientists on Earth to conduct long-term observations of the changing distance between Earth and the moon. Armstrong and Aldrin also took the first close-up lunar surface photographs and collected more than 50 pounds of lunar rocks, which they transported back to Earth for study. After spending two hours and 13 minutes on the moon, they returned to *Columbia*, traveled back to Earth, and safely splashed down in the Pacific Ocean.

In late 1969, the Apollo 12 crew became the second to land on the moon. In 1970, the Apollo 13 mission failed. The explosion of an oxygen tank forced the crew to return to Earth without landing on the moon. Between 1969 and 1972, 12 American men walked on the moon and used specially designed tools to allow them to collect samples from the lunar surface. For example, the crew’s spacesuits were designed to protect them from lunar temperatures between -238 and 248°F (-150 and 120°C) and cosmic radiation. Since the spacesuit gloves limited the crew’s dexterity, scientists developed tools with large-diameter textured grips. Spacesuits were not flexible enough to allow astronauts to bend down. To address this limitation, scientists developed tools with long handles, which allowed astronauts to pick things up with a claw-like device from a standing position.

Additionally, astronauts used a rake-like tool to comb the lunar surface and collect samples of diverse rocks. They used a scoop/shovel-like tool to collect

dust samples. To collect samples from beneath the surface ranging in depth from a few inches (or centimeters) to several yards (or meters), astronauts hammered and drilled collection tubes into the ground. The samples they extracted provided researchers with a cosmic ray history of the moon. After the astronauts and the samples returned to Earth, they were placed in quarantine for days to ensure that they were not carrying microscopic substances that might be harmful to the Earth and its inhabitants. The last Apollo mission to the moon was Apollo 17 (1972). In 1975, Apollo 18 (the last Apollo mission) orbited Earth and docked with the Soviet *Soyuz 19* spacecraft. The Cold War-era Apollo-Soyuz Test Project was an unprecedented cooperative mission between American and Soviet astronauts. This type of U.S.-Soviet cooperative venture did not reoccur until after the Cold War.

Due to the rising costs of space projects during a time of pressing national problems, including an economic downturn, the Apollo Project was terminated in 1975. Although the Apollo Project was not the only U.S. space program, its importance was tied to its unprecedented budget and its chief accomplishment of successfully landing Americans on the moon. In political terms, the project showcased American technological superiority and propelled the United States to victory in the Space Race. In fact, the Soviets never made a successful manned moon landing. In this respect, the U.S. flag, which is still on the moon where Apollo astronauts planted it, took on a much greater significance.

Other notable achievements of the Apollo Project included the first photograph of Earth from space and a better understanding of the history and nature of the moon. Throughout the entire Apollo Project, a total of 900 pounds of lunar material were transported to Earth for investigation. Practical mission needs led to technological innovations in tool designs. Later, some of those tool designs entered the consumer market. In addition, the success and prestige of the Apollo Project encouraged future space projects including the manned Space Shuttle program (1972–2011) that conducted many missions in Earth's orbit, and the two unmanned Voyager (1977–) spacecraft that became the first man-made objects to leave the solar system.

Rolando Avila

See also Jackson, Mary Winston; Johnson, Katherine Goble; National Aeronautics and Space Administration (NASA); Space Science and Technology; Vaughan, Dorothy; Voyager Spacecraft; *Vol. 2, Sec. 3: Television*; *Vol. 3, Sec. 2: Ride, Sally*; Space Shuttle; *Vol. 3, Sec. 3: Jemison, Mae*

Further Reading

- Avila, Rolando. 2006. "Space Exploration." In *Social Issues in America: An Encyclopedia*, edited by James Ciment, 1565–73. Armonk, NY: M. E. Sharpe.
- Beattie, Donald A. 2001. *Taking Science to the Moon: Lunar Experiments and the Apollo Program*. Baltimore: Johns Hopkins University Press.

ARPANET

The Advanced Research Projects Agency Network (ARPANET) set the infrastructure that would become the Internet. ARPANET began as a network of connected university computers. The ARPANET was funded by the Defense Advanced Research Projects Agency (DARPA). The original intent was to develop a network for military command and control after a nuclear attack.

The computer network was based on telephone lines and required a new technology known as packet switching to move data on telephone lines between computers. After its start-up in 1969, ARPANET evolved into several innovations in the early 1970s such as e-mail, a file transfer protocol that allows data to be sent in bulk, and a remote connecting service for network computers. This network grew to connect universities with defense funding across the nation. When the Defense Department pulled out of the project in 1990, it had laid the groundwork for today's worldwide Internet. Universities continued the old network as the National Science Foundation network (NSFnet) as it had expanded to individuals with the advent of the personal computer.

The roots of the ARPANET go back to the funding of DARPA, which was formed in 1957 as a response to the launching of Sputnik. DARPA was created as a very special research group for the Department of Defense. The name was changed in 1958 to Advanced Research

Projects Agency (ARPA). ARPA had a \$12 million annual budget and much flexibility on spending it. Its first project was to look at a communications network that could operate after a nuclear attack on the United States. This bombproof network would allow distant military centers to communicate. ARPA adapted the early work by Paul Baran of the Rand Institute in the 1960s.

This early network research had been financed by the Air Force. Baran's work was on a packet-switching system that would allow information to be routed on any available electronic lines such as telephone lines. Baran's packet-switching concept was a revolutionary idea of breaking data or messages into packets to flow along available lines; the packets would then be reassembled at the destination machine. This differed from a traditional phone call, which used circuit switching to form a dedicated circuit for the duration of the communication session. Packet switching allows data to flow on a fractured network unable to develop a dedicated or "direct" hookup. Packet switching is a special computer protocol allowing computers to exchange information (network control protocol).

Baran's packet-switching network offered another possibility of connecting universities involved in research for the Defense Department. At the time, even computers in the same room could not talk to each other, let alone computers at different universities. Packet switching along telephone lines would be a necessity to move large blocks of research data. These connections would allow huge amounts of data to be transported between universities. Beyond packet switching, some hardware to handle the messages had to be developed. Since ARPA was a small core group, it contracted out the work to BBN Technologies. To connect distant computers, each location required a gateway computer known as an interface message processor (IMP, or router, as it is known today). The first IMP was built by Honeywell and could service four local computers.

The first network connected computers at the University of California, Los Angeles (UCLA) and the Stanford Research Institute in September 1969. UCLA and Stanford both had Scientific Data Systems (SDS) computers. Initially, after the user typed "login," the system shut down; it took another month to work out the bugs for a message, which was ultimately sent at 10:30 p.m. on October 29, 1969.

By the end of 1969, an IBM 360 at the University of California, Santa Barbara and a DEC at the University of Utah were added to the network. The Massachusetts Institute of Technology was added to the network in March 1970. In 1971, the first e-mail was sent; by 1973, there were over 40 sites, and e-mail made up 75 percent of the traffic, auguring the future of the Internet. To send a message on the ARPANET required a computer to break the message into packets using an Internet Protocol (IP). The packets also received a digital identification, because individual packets might take different paths. Individual packets are routed based on traffic. When the individual packet envelopes reach the destination computer, transmission control protocol (TCP) reassembled the message in the correct order. The network was slow, running at 50 to 200 kilobits per second. The year 1971 also brought the use of a terminal interface processor (TIP) capable of adding over 60 slave terminals to the host computer. By the mid-1970s, huge databases were being passed between universities using file transfer protocol (FTP). The ARPANET had achieved its goal and was supporting both military and civilian research applications. In 1983, the ARPANET was split into the NSFnet and the classified military network (MILnet). ARPANET continued as a communication system between certain research pockets at various universities until most of the IMP routers became obsolete in 1989.

The NSFnet used local area networks (LANs) to link whole universities internally and externally. The NSFnet started to look for more funding as the ARPANET shut down in 1990. In 1991, Senator Albert Gore crafted and the Congress passed the High Performance Computing and Communication Act. The bill created and funded a super information highway for research, which evolved into the Internet of today. Today's Internet is made up of the same infrastructure of routers and protocols. The Internet, regardless of its government origins, has remained firmly rooted in private industry.

Quentin R. Skrabec

See also: IBM 360 Computer; Universal Automatic Computer (UNIVAC); *Vol. 3, Sec. 2:* Internet; Personal Computer (PC); *Vol. 3, Sec. 3:* Google

Further Reading

- Abbate, Janet. 1999. *Inventing the Internet*. Cambridge, MA: MIT Press.
- Banks, Michael. 2010. *On the Way to the Web: The Secret History of the Internet and Its Founders*. New York: Apress.
- Hafner, Katie. 1998. *Where Wizards Stay Up Late: Origins of the Internet*. New York: Simon & Schuster.

Aspartame

Aspartame is an artificial or nonnutritive sweetener formed from the methyl ester of aspartic acid and phenylalanine. G. D. Searle chemist John Schlatter unintentionally discovered the compound in 1965 while developing a new ulcer medication. In 1981, Searle made aspartame, branded as NutraSweet, available for consumer purchase. Aspartame has long been opposed by some public health advocates, but no credible studies have found it hazardous to human health. Aspartame remains one of the most popular artificial sweeteners in the United States.

Saccharine, Predecessor to Aspartame

Saccharine was the first mass-produced artificial sweetener. In 1879, Johns Hopkins University chemist Constantin Fahlberg accidentally stumbled upon the solution while attempting to formulate a new food preservative. After serendipitously tasting the residue of an apparently unremarkable batch, he noted its extreme sweetness and took to calling it “saccharine,” meaning of, or similar to, sugar. Fahlberg quickly sought business partners and tirelessly marketed saccharine to food and beverage manufacturers.

Late-19th-century Progressivism brought the issue of dubious additives into public discourse, and in an era before the 1906 Pure Food and Drug Act, consumers had no idea they were ingesting anything other than cane sugar. The year the act was passed, reformist and chief chemist of the U.S. Department of Agriculture Harvey Wiley submitted a proposal to ban saccharine based on its questionable science. President Theodore Roosevelt personally intervened to keep the sweetener legal, probably because he enjoyed it at the advice of his doctor. (Physicians frequently recommended

saccharine to alleviate ailments such as diabetes or, in Roosevelt’s case, obesity.)

Nonetheless, consumers understood sugar to be part of a wholesome diet. Food and beverage advertisers labeled saccharine-laden competitors as unnatural and nonnutritive. Only mandated World War II-era sugar rationing recovered saccharine from obscurity. Families continued to use saccharine after the war, especially once nutrition science linked excess calories to poor health. By the late 1950s, saccharine was fully commoditized and added to a variety of foods and beverages, and it was also available in packets under the brand name Sweet’n Low.

Aspartame and the Decline of Saccharine

Several factors allowed aspartame to quickly dominate the market once it was commercially introduced in 1981. As early as the 1960s, the implications of a chemical food supply distressed a growing number of Americans. Youth counterculture rejected several aspects of mainstream society, including the inherently artificial nature of saccharine. Others based their concern on scientific evidence. Rachel Carson’s 1962 *Silent Spring*, a widely read exposé of the deleterious effects of DDT pesticide on human health, called into question the chemical processes of American food production. Sufficiently alarmed readers regarded chemical products with deep suspicion.

G. D. Searle executives believed they had found the solution in aspartame once Schlatter had accidentally prepared the sweet solution. The pharmaceutical company branded aspartame NutraSweet and spent more than a decade quietly preparing the product for commercial release. Corporate scientists continually refined aspartame, resulting in a substance free from the bitter aftertaste and high-temperature breakdown of saccharine.

NutraSweet benefited from lengthy product development as the U.S. Food and Drug Administration began intensively reviewing artificial sweeteners. Throughout the 1950s and 1960s, several major studies on the health effects of saccharine had proved inconclusive. A 1977 trial by the Canadian Health Protection Board found a link between saccharine consumption and bladder cancer but only at amounts equivalent to

over 800 diet sodas per day. Still, in March of that year, the FDA announced its intention to ban saccharine on January 1, 1978. Hundreds of thousands of protest letters swiftly flooded offices of the FDA and elected representatives. Writers mocked the extreme research circumstances, promoted their right to choose, and shared deeply personal stories of weight loss attributed to saccharine. The FDA eventually relented to political pressure. Americans might have distrusted saccharine, but they feared the alternative more.

After 1977, Searle understood better than ever the perils of government scrutiny. NutraSweet was subjected to internal safety trials, eventually exceeding all regulatory standards. For added insurance, just as the FDA abortively prepared to ban saccharine, Searle staffed the NutraSweet management team with well-connected outsiders: former congressman and secretary of defense Donald Rumsfeld as CEO, Firestone executive James Denny as CFO, and attorney Bob Shapiro as president. NutraSweet promised a better-tasting, scientifically vetted, and politically untouchable replacement for the embattled saccharine.

NutraSweet first entered the market in powder form in 1981 and was included in prepared food and beverages after 1984. Aspartame became an instant success. NutraSweet profits grew yearly, and in 1985, the brand was acquired by Monsanto. That same year, historian Carolyn de la Peña reports, Americans consumed roughly 800 million pounds of aspartame, and by 1990, more than 1,200 aspartame-containing items lined grocery store shelves. In 1985, NutraSweet also introduced blue packets of Equal sweetener for easy household and restaurant use. The NutraSweet patent expired in 1992, but aspartame sales volume continued to grow. Currently, more than 6,000 supermarket products list aspartame as an ingredient.

Public Health Concerns

Throughout the 1980s, scientific consensus considered aspartame safe. In fact, as the release of NutraSweet neatly coincided with an expanding diet movement, many doctors steered overweight patients toward aspartame to help control weight. As NutraSweet approached its 10th anniversary, however, some public health advocates began voicing their dissent. A slew of

anti-aspartame books and documentaries were released in the 1990s, whose writers ranged from passionate laypeople to concerned physicians. These polemics generally rely upon anecdotal evidence in claiming aspartame responsible for a number of symptoms including headaches, indigestion, dizziness, and even blindness. Current medical and scientific opinion finds no harm in moderate aspartame consumption.

Kyle Bridge

See also *Vol. 2, Sec. 1: Saccharine; Vol. 3, Sec. 3: Genetically Modified Foods*

Further Reading

- de la Peña, Carolyn. 2010. *Empty Pleasures: The Story of Artificial Sweeteners from Saccharine to Splenda*. Chapel Hill: University of North Carolina Press.
- Magnuson, B. A., et al. 2007. "Aspartame: A Safety Evaluation Based on Current Use Levels, Regulations, and Toxicological and Epidemiological Studies." *Critical Reviews in Toxicology* 37, no. 8: 629–727.

Association for Women in Mathematics (AWM)

The Association for Women in Mathematics (AWM) is a nonprofit organization founded at the Joint Mathematics Meetings held in Atlantic City, New Jersey, in 1971. AWM's mission is to encourage women and girls to study and pursue active careers in the mathematical sciences and to promote equal opportunity and the equal treatment of women and girls in the field. By 2015, the AWM had more than 3,000 members (women and men) representing a broad spectrum of the mathematical community.

In the late 1960s, female mathematicians had been informally organizing, especially in the Boston area at Wellesley College. AWM founding president Mary Gray is largely credited with creating the organization after Joanne Darken, then an instructor at Temple University, suggested that the women of the Mathematics Action Group form their own caucus. Gray is said to have insisted on attending an American Mathematical Society (AMS) council meeting, which until then was open only to men by "gentleman's agreement."

A perhaps apocryphal history says that Gray's answer paraphrased the character Eowyn in *The Lord of the Rings* when she responded, "I am no gentleman." In any case, she stayed at the meeting, which eventually led to the meetings being officially open to observers. The AMS had existed since 1888, with participation by females discouraged until Charlotte Scott had joined in 1891.

Gray's original goals for the organization included equal consideration for admission to graduate school and support while there; female faculty appointments at all levels; equal pay for equal work; equal consideration in assignment of duties and for promotion and tenure; administrative appointments at all levels in universities, industry, and government; and equal access to government grants, positions on review and advisory panels, and positions in professional organizations. While these seem like basic requests today, they were not so in the early 1970s and caused some women to avoid aligning with the group for fear that being considered radical would keep them from being hired.

From the beginning of the AWM, a regular newsletter has been an organizational and communication tool. AWM events at conferences have included scientific talks by female mathematicians and panel discussions on challenges faced by women in the field.

Some events have focused on historical figures or underrepresented groups, such as the panel Black Women in Mathematics organized by Patricia Kenschaft and Etta Falconer and held in Atlanta, Georgia, in January 1978. At that time, of the 12 black women in the United States holding PhDs in mathematics (more, of course, held degrees in mathematics education), 6 were on the panel.

Men compose about 13 percent of the AWM's membership. They become members for a variety of reasons, mostly to show support for women in mathematics. All hold the belief that society stands to benefit from developing the mathematical talents of women.

From the organization's inception, AWM publications, workshops, conferences, and prizes have highlighted outstanding research by women in mathematics and mathematics education and have supported those seeking a career in mathematics through mentoring and network building.

Over the years, AWM activities have grown to include programs for K-12 girls, networks for teachers,

and student chapters for undergraduates and graduate students. The AWM has also advocated for fair treatment and a positive environment for women in mathematics-related fields.

By 2013, AWM's efforts resulted in studies showing that women earned 41 percent of the PhDs in STEM (science, technology, engineering, and math) fields. The downside of the studies showed that women were only represented in 28 percent of tenure-track faculty in those fields in universities across the country. This is a continuing issue, since women in STEM fields earn nearly 33 percent more than those in non-STEM careers, and the wage gap between men and women in STEM careers is smaller than in other fields.

Rachel Levy

See also Haynes, Martha Euphemia Lofton; Jackson, Mary Winston; Johnson, Katherine Goble; Vaughan, Dorothy; *Vol. 2, Sec. 1: Harvard Computers; Vol. 2, Sec. 2: Noether, Amalie Emmy*

Further Reading

- Blum, Lenore. 1991. "A Brief History of the Association for Women in Mathematics: The Presidents' Perspectives." *AMS Notices* 38 (September).
- Henrion, Claudia. 1997. *Women in Mathematics: The Addition of Difference*. Bloomington: Indiana University Press.
- Kenschaft, Pat. 1981. "Black Women in Mathematics in the United States." *American Mathematical Monthly* 8.
- Taylor, Jean E., and Sylvia Wiegand. 1999. "AWM in the 1990s: A Recent History of the Association for Women in Mathematics." *AMS Notices* 46 (January).

Atari

Atari Inc., founded in Sunnyvale, California, in 1972 by Nolan Bushnell and Ted Dabney, was a pioneer in arcade games, home video game consoles, and home computers. The company's products, such as *Pong* and the Atari 2600, helped define the electronic entertainment industry from the 1970s to the mid-1980s.

Bushnell majored in electrical engineering at the University of Utah, where computer graphics had recently been invented. He found fascination with one



A 1977 Atari computer console with paddle controllers and assorted games, but not the accompanying joystick. (Science & Society Picture Library/Getty Images)

of the first video games, *Spacewar*, developed at the Massachusetts Institute of Technology. During breaks from school, Bushnell worked at a pinball arcade, and eventually he would mesh both those worlds with Atari.

Bushnell and Dabney met in 1969 while working for Ampex and began working on video game ideas, which led to the 1971 release of *Computer Space*. It sold 1,500 units, which was far from a hit, but it made Bushnell and Dabney enough money to start their own company dedicated to the creation and manufacture of what they called coin-operated electronic games. After choosing a name that was already taken by another California company, they switched to Atari because “*ataru*” means “to hit a target” in Japanese and came from an ancient Chinese board game called “go” that

Bushnell enjoyed playing. He had essentially chosen the company’s name from among its strange jargon.

Dabney focused his attention on developing early spot motion circuit technology, which allowed dots to move around on a screen. The company hired a new engineer, Al Alcorn, and he helped it create its first major hit, *Pong*, in 1972. It could be played on video game cabinets in pinball arcades. When they released a home video game of *Pong* in 1975, the company sold 150,000 units. There had been earlier forms of video table tennis games, but *Pong*’s ball sped up as the game went on and pinged off the paddles at different angles depending on where it was hit. The gaps at the top of the screen, actually the result of a quirk in the technology rather than intention, ensured that there

was always a small space for the ball to disappear, ending the game. Also, *Pong* had sound, a feature that previous games had lacked.

Off the success of *Pong*, Bushnell was able to sell Atari to Warner Communications for \$28 million. In five years, sales of Atari home video systems had reached \$415 million, and the company released its first personal computer.

Jack Tramiel, ex-CEO of Commodore, bought Atari in 1984. Tramiel released the mildly successful Atari ST home computer, and sales topped \$25 million in 1986. But six years later, Nintendo brought an antitrust lawsuit against the company and won. Atari tried to deflect that loss by releasing the Jaguar video game system as competition to Nintendo, but the system's exorbitant price dissuaded customers, who tended to buy Nintendo's more economically priced products.

In 1994, Sega game systems traded \$40 million for all of Atari's patent rights, but it did not help right the company. In 1996, a new Interactive division failed, and JTS, a maker of computer disk drives, bought it out, only to sell Atari assets (copyrights, trademarks, and patents) as intellectual property scraps two years later to Hasbro Interactive for \$5 million.

Rosanne Welch

See also Commodore 64; *Pong*; Vol. 3, Sec. 2: Apple; Computer/Information Technology; Microsoft; Vol. 3, Sec. 3: Blizzard Entertainment

Further Reading

Vendel, Curt, and Marty Goldberg. 2012. *Atari Inc.: Business Is Fun*. New York: Syzygy Press.

Automotive Technologies (Post–World War II)

Since the end of World War II, the number and variety of technologies incorporated into automobiles have increased significantly while their prewar technologies have been subjected to numerous iterations, variations, and improvements. Each of the systems within an automobile's design relies on a combination of various technologies—many of which have applications in other industries—working in concert to give an

automobile its function. From the manufacturing of its parts and the construction of the vehicle itself to its operation and maintenance, automotive technologies draw from various disciplines of engineering and design to create a finished and functioning product. With the number of automobiles in use globally having exceeded 1 billion in 2010 and projected to double in the coming decades, automotive technologies have significant individual, localized, and global implications, including for human health, economic development, and environmental and ecological health.

As the American economy recovered after World War II, the American auto industry experienced a rapid increase in demand in response as U.S. military forces drew back and soldiers returned from the war. As the industrial sector transitioned back to a peacetime economy, much manufacturing capacity previously dedicated to producing military equipment was repurposed by automakers to meet the growing demand for cars. Facing increased corporate consolidation and market share competition within the industry, illustrated by the dominance of the “Big Three” (i.e., GM, Ford, and Chrysler), American automakers widely adopted the practice of incorporating dynamic obsolescence into automobile design. Also known as built-in or planned obsolescence, “dynamic obsolescence” is a term that denotes the deliberate design of a product to have a limited useful life to promote recurring consumer demand. This practice would, to a great extent, shape the rate and direction of technological advancement in automotive engineering and design, promoting incremental technological improvements bound to social, industry, and market forces.

Throughout the 1950s, various innovations that were devised before and during the war for luxury or military applications were widely implemented by American automakers into consumer automobiles. A comprehensive list of all these innovations would be extensive, but several are especially notable, including the V8 engine, automatic transmissions, and independent suspensions.

A V8 engine is a kind of combustion engine with eight pistons arranged in a V-shaped configuration. Automakers had incorporated the V8 engine, or the overhead valve V8 engine, in automobiles as early as the 1910s. However, it was not until after the war, as average

vehicle tonnage began to increase, that automakers started to offer V8 engines to consumers more widely.

The term “automatic transmission,” also known as “self-shifting transmission,” denotes a type of power transmission system within an automobile that converts and controls the energy output of an engine to the vehicle’s drive wheels without the direct input of a driver. While such transmissions were first developed in the 1930s and incorporated into wartime automobile models, automatic versions were not used in most cars until after the war. Over time, several variations of automatic transmissions have been developed, including continuously variable transmissions (CVTs), semiautomatic transmissions, and the hydraulic automatic transmission. While automakers still feature manual transmissions, notably in performance and racing cars, automatic transmissions reduce the actions and inputs required of the driver.

“Independent suspension” is a term for the system that allows a vehicle’s axles, the shafts used to transfer torque to its wheels, to react to road conditions independently of each other. Beginning in the 1950s, this type of suspension became more common.

These and other technological innovations in the 1950s coincided with the enactment of the Federal-Aid Highway Act of 1956, otherwise known as the National Interstate and Defense Highways Act. Signed into law by then president Dwight D. Eisenhower, it spurred the construction of a network of highways across the nation. Though these new roads brought great benefits, as more drivers took to them, the number of fatal crashes in the United States rose significantly.

Beginning in the 1960s, consumers pressured carmakers to incorporate new safety technologies, including design adjustments to the chassis to better protect the driver and potential pedestrians in the event of a collision; changes to the layout and construction of the instrument panel or dashboard to reduce distractions to the driver; as well as improvements to the transmission, steering wheel, tires, head rests, windshield, etc. Perhaps the most notable safety improvement was the three-point seatbelt system, and later, the airbag. The National Traffic and Motor Vehicle Safety Act passed in 1966, mandating the federal government to establish and enforce traffic and safety regulations.

Innovations in automotive technologies have increasingly responded to government regulation. In the United States, the regulation of automobiles and their parts and technologies are the responsibility of federal agencies, including the National Highway Traffic Safety Administration (NHTSA) and the Environmental Protection Agency (EPA). Both were formed in 1970, during the Nixon Administration. The NHTSA regulates safety standards, and the EPA places restrictions on the chemical composition of combustion engine fuels to control air pollution. For instance, EPA regulations in the 1970s and 1980s prompted the development of the catalytic converter, an exhaust emission control device that reduces the toxicity of a vehicle’s gas exhaust.

Since the 1950s, electronic and computer systems have been increasingly integrated into automobiles. Today, they rely on electronic control units, or ECUs, to regulate and monitor most of a vehicle’s operations. This proliferation of electronic technology has coincided with innovations in computer design, especially the development of semiconductors and their use as transistors in microprocessors. Many electronic and computer systems are standard in cars today, including navigation systems like GPS; Internet and radio; collision detection and warning systems, etc. Autos functions are more automated—there are even autonomous or self-driving automobiles today.

Advancements in battery and energy storage technologies, along with increased awareness of the environmental and health effects of fossil fuel consumption, have prompted a resurgence of hybrid-electric (HEVs) and electric vehicles (EVs). HEVs and EVs rely on much of the same technology that gas-powered cars engines do, but HEVs utilize electric generators in addition to combustion engines while EVs rely on electricity exclusively. HEVs and EVs produce little to no carbon dioxide exhaust or other, more toxic chemicals, and thus they are often seen as reducing the environmental impact of driving.

As automobiles have become ubiquitous, their technologies have increasingly been scrutinized by consumers, government, and the industry itself. Innovations in automotive technologies do not occur in a vacuum; nor are the effects of their usage restricted to the performance of the vehicle.

D. L. Barnum

See also Climate Change; Electric Car; Petroleum Industry (Post–World War II); *Vol. 3, Sec. 2: Artificial Intelligence (AI); Self-Driving Cars; Vol. 3, Sec. 3: Hybrid Vehicles*

Further Reading

- Hyde, Charles K. 2013. *Arsenal of Democracy: The American Automobile Industry in World War II*. Detroit: Wayne State University Press.
- Nader, Ralph. 1965. *Unsafe at Any Speed: The Designed-In Dangers of the American Automobile*. New York: Grossman.
- Rubenstein, James M. 2008. *Making and Selling Cars: Innovation and Change in the U.S. Automotive Industry*. Baltimore: Johns Hopkins University Press.

Baer, Ralph (1922–2014)

Rudolf Heinrich Baer, known as Ralph Baer, is said to be “the Father of Video Games,” as he paved the way for the future of video gaming consoles with his once-ignored vision of future entertainment. Video gaming has grown to be a billion-dollar industry with no signs of slowing down. Before the Xbox One, PS4, and Wii-U, there was the “Brown Box,” the first home video console. Had it not been for Baer’s desire to create an interactive game through an electronic medium, the video gaming industry might not be what it is today.

Baer was born on March 8, 1922, in Germany, where he lived for 16 years before moving to the United States in 1938 in search of refuge from the Nazis. In his first two years in the States, he graduated from the National Radio Institute as a service technician for radios. He served for three years in the U.S. Army during World War II, and then received a BS in television engineering from the American Institute of Technology 1949. Afterward, he joined a succession of electronics firms.

In 1951, Baer worked for Loral Electronics, a company associated with military development. Its chief engineer, Sam Lackoff, asked Baer to build a television set. Baer thought of adding some kind of game to it, but Lackoff felt that this was a waste of time. In 1966, Baer wrote a proposal for how a device could be

hooked up to television set that would allow games to be played on the screen. He described the possibility of action-based, artistic, and instructional games. He pitched the idea to Sanders Associates, his current firm, and it funded his research.

Baer worked with Bob Tremblay, a Sanders technician, to develop the products. After many tests, they finally created the “Brown Box” that allowed people to play multiplayer games such as ping-pong and volleyball on the television screen. The Brown Box, which would later be renamed the “Odyssey” by the Magnavox company in 1971, was the first home video game console.

Baer was awarded the National Medal of Technology by President George W. Bush in February 2006.

Baer’s success continued beyond his Brown Box. He later grew his own business around electronic toys and games, including Milton Bradley’s *Super Simon*. He continued to contribute to the industry until his passing on December 6, 2014. The Academy of Interactive Arts and Sciences gave him the 2015 Pioneer Award posthumously.

Dannela Azul Valencia

See also *Vol. 2, Sec. 2: Radio; Vol. 2, Sec. 3: Television; Vol. 3, Sec. 3: Video Game*

Further Reading

- “The Father of the Video Game: The Ralph Baer Prototypes and Electronic Games.” National Museum of American History. <http://americanhistory.si.edu/collections/object-groups/the-father-of-the-video-game-the-ralph-baer-prototypes-and-electronic-games>, accessed September 25, 2018.
- “Lemelson—MIT Program.” Ralph Baer. <http://lemelson.mit.edu/resources/ralph-baer>, accessed August 31, 2018.
- “Odyssey—Ralph Baer’s Strange Odyssey.” The Dot Eaters. <http://thedoteaters.com/?bitstory=odyssey>, accessed August 31, 2018.
- “Oral History of Ralph Baer.” 2006. Interview by Gardner Hendrie. Computer History Museum. October 12. http://archive.computerhistory.org/resources/text/Oral_History/Baer_Ralph_1/Baer_Ralph_1and2.2006.102657972_final.pdf, assessed September 25, 2018.

Primary Document: Excerpt from Ralph Baer's Four-Page Paper Describing His Plans for Simple Video Games (1966)

*Ralph Baer is known for creating the first-ever video game console back in the late 1960s. This excerpt is from his notes explaining his vision of the video game console, which were read during a patent infringement court case, *Magnavox v. Bally et al.*, consolidated case number 74 C 1030 (1975). In it, he mentions how the console was to connect to the television as well as the types of games to be created for it, such as action, artistic, and instructional games.*

1. Intent

The purpose of the invention is to provide a large variety of low-cost data entry devices which can be

used by an operator to communicate with a monochrome or color TV set of standard, commercial unmodified type. Entry into the TV set is to be gained either through direct connection to the video system (at 2nd detector) or by connection to the antenna terminals, thus substituting the entry device (hereinafter called "generator") for the broadcast TV signal, by modulating an RF oscillator operating on one of the several standard TV channel frequencies, and tuning the TV set to that channel (channel LP for Let's Play). . . .

Source: *Magnavox v. Bally et al.*, consolidated case number 74 C 1030 (1975).

Bar Code Scanner

Historians have now heralded June 26, 1973, when a pack of Wrigley's Juicy Fruit Gum was scanned at a Troy, Ohio, supermarket, as the beginning of commercial bar codes by enshrining the pack of gum in the Smithsonian. However, the history of bar codes and code scanning goes back to the 1940s. Even though initial capital and equipment investments could be as large as a million dollars, studies showed that there would be a payback in less than three years. In addition, food processors would have to invest heavily in the new technology. The cost of the equipment fell over time, and new applications and savings quickly surfaced. However, progress was hindered by the resistance of unions, manufacturers, and consumers, which slowed overall implementation.

The bar code is a visual code in an optical, machine-readable format. In the late 1940s, Bernard Silver and Norman Woodland of the Drexel Institute of Technology realized that reading product information, such as the price, at the checkout registers of grocery stores—as well as keeping track of sales and inventory—was critical to the profitability of supermarkets. Woodland and Silver received a patent for

their system based on Morse code and an optical reading system adapted from the de Forest movie sound system, which allowed reflected data to be converted into sound. The system had serious commercial limitations, but the patent rights were sold to IBM in 1951 and to Philco and then to RCA in 1963. All of these companies became actively involved in the development of a commercial bar code system. In the late 1950s, railroads tried to use such systems to identify railroad cars but had limited success.

The motivation to fully develop a bar code system came from the National Association of Food Chains, which recognized that it could reduce costs and boost inventory control for supermarkets. In 1966, the association worked with RCA, owner of the Silver and Woodland patent, on developing a system, and Kroger offered to be a test company for it. The industry group also requested the help of other companies working on bar codes such as IBM, National Cash Register, and Singer. In 1973, the RCA system (using an IBM coding label) was successfully tested at Marsh's Supermarket in Troy, Ohio. The IBM code would become the universal product code and the industry standard. The code was split into two halves of six digits each. The first digit differentiated products between those of



Bar code scanners revolutionized check-out processes, the shipping of boxes, and inventory counting. By reading codes in one swipe, productivity increased dramatically. (Bacho12345/Dreamstime.com)

variable and nonvariable weight. The next five digits were the manufacturer's code, the next five coded the product, and the final digit was for control. Pricing was handled in the software. For years, product prices were still marked on them because customers demanded it.

The system was expensive, and the economic studies were mixed. IBM's own studies showed that to fully realize the predicted savings, 70 percent of the store's products had to be coded. The National Association of Food Chains continued its support in spite of questionable economic analyses, pushing for compliance by food manufacturers to reach the 70 percent implementation by the end of the 1970s. By 1980, 8,000 supermarkets had bar-coding scanners. Unfortunately, the equipment cost, customer resistance, and technology

issues did not allow the grocery industry to realize the projected savings.

Simultaneously, other industries and companies were advancing the technology. Computer Identics Corporation was working on the application of codes for manufacturing industries. Its founder, David Collins, had worked in the early 1960s on the failed application of bar codes in the railroad industry. Computer Identics Corporation was using the cutting-edge technology of laser readers by 1970. These scanners were much better than the 500-watt-lightbulb system of the Woodland patent. Lasers could read codes quickly and accurately. Even before the famous scan of a packet of gum, Computer Identics was using its system at General Motors to identify, monitor, and track car axles at manufacturing plants. Engineers might argue that this was the first bar code system in 1969, but it lacked the standardized and uniform code that was being developed for the grocery industry. The laser technology, however, would hold the key to the bar code's full commercial success in the 1990s.

By the late 1990s, the bar code had led to billions of dollars in savings for manufacturers and retailers, the biggest savings coming from improved inventory control, marketing and sales analysis, and monitoring of sales trends. It also helped reduce shoplifting as well as the number of employees. The full implementation of automatic checkout was slow during the 1990s, as there was union resistance, consumer resistance, and the need for good verification systems. After 10 years, the full savings of automated checkout were being realized. Manufacturing use of bar codes for inventory control is also reaching full implementation.

The retail industry continued to advance the technology with QR codes in 2005, which allow cell phone users to read them; they are linked to related Web sites to allow shoppers to compare prices and product information. Applications in the logistics industry for tracking have also been fully implemented. Bar codes have also spread to hospitals and research organizations.

Quentin R. Skrabec

See also IBM 360 Computer; *Vol. 2, Sec. 1: Cash Register*

Further Reading

- Kato, Hiroko, Keng T. Tan, and Douglas Chai. 2010. *Barcodes for Mobile Devices*. Cambridge: Cambridge University Press.
- Palmer, Roger C. 2007. *The Bar Code Book: A Comprehensive Guide to Reading, Printing, Specifying, Evaluating, and Using Bar Code and Other Machine-Readable Symbols*. 5th ed. Bloomington, IN: Trafford.

Benerito, Ruth Rogan (1916–2013)

Ruth Rogan Benerito was an American chemist and inventor known for her work related to the textile industry, especially the development of wash-and-wear cotton fabrics. She also had 55 patents and was said to have saved the cotton industry with her discovery of a method for constructing wrinkle-resistant cotton.

Benerito was born in 1916 in New Orleans, Louisiana. She was only 15 when she began at H. Sophie Newcomb Memorial College, which was the women's school at Tulane University. She then received her bachelor's degree in chemistry in 1935 and her master's in physics in 1938. Later, she attended the University of Chicago, where she earned her PhD in physical chemistry in 1948.

Cotton was a dominant crop in the American South, where Benerito was raised in the 1900s. The lightweight and breathable fabric was the material of choice for everyday living. One of the major drawbacks of early cotton fabric is that it would wrinkle easily during washing, which made ironing a mandatory step to make it wearable. Depending on how big one's household was, this chore could take up a big chunk of someone's day when one could be doing something more beneficial—like making money. Synthetic fabrics were later developed, like polyester and nylon, and took a share of the fabric market. Though they could be worn without ironing, they were much less comfortable compared to cotton. A group led by Benerito proposed a chemically treated cotton that would eliminate the ironing process. This method of attaching organic chemicals to cotton fibers is known as “cross-linking.” Benerito and her team made cotton

fabric not just wrinkle resistant but also stain and flame resistant. Wrinkle-free cotton is, in fact, considered one of the most significant technological developments of the 20th century.

During the Korean War, Benerito developed a way to deliver fat intravenously to patients who were too sick to eat. This method was used to feed seriously wounded soldiers at the time and saved many lives.

At the age of 86, she received the prestigious Lemelson-MIT Lifetime Achievement Award for her work on textiles and her commitment to education. For her role in the textile industry, Dr. Benerito was inducted into the National Inventors Hall of Fame in 2008. She later passed away at her home in Metairie, Louisiana, at the age of 97.

Greg Salcido

See also *Vol. 1, Sec. 3: Rotary Hook (for Sewing Machines); Sewing Machine, Automated*

Further Reading

- Benerito, R. R., J. B. McKelvey, and R. J. Berni. 1966. “A New Theory of Resiliency in Cotton.” *Textile Research Journal* 36: 251–64.
- Sway, Rachel. 2017. *Trailblazers 33 Women in Science Who Changed the World*. New York: Random House.

Biodiesel

Invented first but then overtaken by the popularity and low cost of diesel fuel, biodiesel is a form of renewable fuel made from vegetable oil or through rendering animal fat. International biodiesel is a fuel composed of mono-alkyl esters of long-chain fatty acids that meet international ASTM D 6751 processing standards. These fuels can be used directly in diesel engines or for mixing with petroleum diesel-based fuels. Currently, biodiesel is used by commercial automobiles in mixed petrodiesel blends, in heavy agricultural and construction machinery, and in local transportation such as short-travel railways. Biofuels are one of the many possible responses to creating cleaner burning fuels, an important, leading global issue in the face of

climate change and the dissipating ozone layer. Oddly enough, biodiesel had been invented before these issues were seen as problems.

Experiments into ways to extract fuel in this fashion had begun as early as the mid-1800s, before gasoline took over the market. Using a process known as “transesterification,” E. Duffy and J. Patrick honed the process using only pure, unprocessed vegetable oil. Then Rudolph Diesel created the first diesel engine in the 1890s, feeling that it would be far superior to the steam engine, which used high-pressure compression to ignite its fuel. He presented an engine powered by peanut oil at the 1900 World’s Fair. This fueled an interest in vegetables as an alternative to petroleum, but the idea faded due to issues with the viscosity of vegetable oils. Also, petroleum-based fuels started to become mass-produced and thus cheaper than biodiesels.

Although biodiesels are normally made from vegetable oils or animal fat, other sources are now being researched. One alternative is the use of algae. A major benefit from using algae is that it does not require farmland or fresh water, because it can be grown in water treatment plants. Also, algae do not consume edible source material that is better used to feed people. Other products being researched include fungi, coffee grounds, and sewage. All of these sources undergo the same process of transesterification for creating fuel.

The process can be done in various ways, including the common batch process, the supercritical process, the ultrasonic method, and the microwave method. The process uses methanol to create mono-alkyl esters. If denser alcohols such as ethanol and butanol are used, the biodiesel can perform at lower temperatures, but the yield from the transesterification is not as high. A by-product of the process is the creation of glycerol, which, because of the recent surge in production of biodiesels, has flooded the market.

In comparison to petroleum-based diesel, biodiesel comes close in energy yield. One hundred percent biodiesel is only 10 percent less efficient than petroleum-based diesel. Biodiesel is also better for lubricating diesel engines. Standard diesel leaves behind sediment, while biodiesel dissolves this sediment and does not create other waste products. Biodiesels do

have a higher flash point of combustion. Depending on its base, biodiesel’s flash point is usually 266°F or 130°C compared to petroleum-based diesel, which ignites at around 147°F or 64°C.

Biodiesel also has a high freezing point and gels at higher temperatures than low-sulfur petroleum gasoline. The freezing point depends on the source; biodiesel made from canola seed has a freezing point of 14°F or -10°C, while that made from tallow has a freezing point of 61°F or 16°C. Biodiesels are completely safe and nontoxic because they are biodegradable, degrading four times faster than petroleum-based diesels.

Biodiesels produce 78 percent less carbon monoxide when made with no sulfur impurities; biodiesels can burn sulfur free, preventing a major contributor to acid rain. They also burn 56 percent less hydrocarbon and are 94 percent lower in carcinogenic properties than standard diesel.

In the United States, there has been an increase in biodiesel use over the last couple decades to combat higher gasoline prices at the fuel pump and reduce the country’s dependence on oil-producing nations. From producing only around 25 million gallons in the early 2000s to around 2.1 billion gallons by 2015, the United States is on track to replace 10 percent of all petroleum diesel fuel by 2022, although it is now considered more as an additive than a complete replacement. Creating blends of the two fuels would reduce the sulfur impurities in petroleum-based diesel while also increasing its lubricity. Blends would also lower the total amount of harmful contaminants in emissions, creating healthier areas for anyone who works in close proximity of said emissions. The rise in electric-powered vehicles might make a dent in the popularity of biodiesels, as much remains in flux regarding the most planet-friendly way to fuel travel and trade.

Rosanne Welch

See also Petroleum Industry (Post–World War II); *Vol. 3, Sec. 2: Self-Driving Car*

Further Reading

Luque, R., and J. A. Melero, eds. 2012. *Advances in Biodiesel Production: Processes and Technologies*

(*Woodhead Publishing Series in Energy*). Cambridge: Woodhead.

Marcel, Kurt, ed. 2015. *Biodiesel: Advanced Approaches and Applications*. New York: Clanrye International.

Pahl, Greg, and Bill McKibben. 2008. *Biodiesel: Growing a New Energy Economy*. White River Junction, VT: Chelsea Green.

Primary Document: Statement of Anne Steckel, the Vice President of Federal Affairs of the National Biodiesel Board, to the Senate Committee on Environment and Public Works (2016)

On February 24, 2016, Anne Steckel, the vice president of federal affairs for the National Biodiesel Board, gave testimony on the need for growth in advanced biofuels in the United States, specifically biomass-based diesel. She spoke before the Energy and Commerce Committee's Subcommittee on Energy and Power chaired by Senator James Inhofe and ranking member Senator Barbara Boxer. Steckel's expertise in the field came from years of overseeing legislative issues for several members of Congress and directing government relations for the American Farm Bureau Federation and for Growth Energy, a renewable fuels trade group.

Written Statement of Anne Steckel Vice President of Federal Affairs, National Biodiesel Board Senate Committee on Environment and Public Works United States Senate Oversight of the Renewable Fuel Standard February 24, 2016

Chairman Inhofe, Ranking Member Boxer, and other members of the Committee, I appreciate the opportunity to provide a written statement regarding the Renewable Fuel Standard (RFS) and the EPA's recent action setting annual volume standards.

Our comments today will focus on our continued efforts to grow the Biomass-based Diesel and Advanced Biofuel categories of the RFS. Biomass-based Diesel—commonly referred to as “biodiesel”—includes both biodiesel and renewable diesel, and qualifies as an Advanced Biofuel under the program.

In creating the RFS, Congress and the Administration of President George W. Bush sought to substantially increase domestic renewable fuel production in an effort to reduce our dependence on petroleum, to create jobs and economic activity in a new American energy industry, and to reduce harmful emissions. The law particularly sought to promote the development of Advanced Biofuels—those reducing greenhouse gas emissions by at least 50 percent.

To date, biodiesel is the first and only EPA-designated Advanced Biofuel under the program to reach commercial-scale production nationwide. Since the RFS was created, biodiesel has grown from a niche fuel to a commercial-scale industry with a record U.S. market of nearly 2.1 billion gallons last year, all made from an increasingly diverse mix of resources including recycled cooking oil, soybean oil and animal fats. Biodiesel's growth is proving that Advanced Biofuels are achieving the goals of the RFS.

Those goals are as compelling today as they were when Congress initially created the RFS with overwhelming bipartisan support in 2005. While most of us appreciate the low prices we are currently seeing at the fuel pump, we should not be lured into complacency. All of us know that oil prices rise and fall, often under the influence of nations and cartels that do not have our best interests at heart. We understand that fuel prices will rise again in the not too distant future, and Americans expect our elected officials to work on solutions. We must continue to develop and incentivize alternative fuels to protect American consumers from these price fluctuations, and to ensure that our economy is not overly dependent on a single, globally traded commodity. Doing so requires consistent, long-term policy.

We also must continue to develop new fuels that reduce harmful pollutants, including carbon emissions, which are creating costly public health problems along with tremendous burdens on public infrastructure. And we must incentivize new technologies that create the jobs of the future and keep the United States at the forefront of advances in the energy sector.

The RFS is working to do all of those things in a cost-effective way that helps consumers.

The National Biodiesel Board has worked closely with the EPA, including EPA Administrator Gina

McCarthy, Acting Assistant Administrator Janet McCabe, and their very capable team led by Director Christopher Grundler. We appreciate the EPA's hard work to get the annual process of establishing volume standards back on track from a timing perspective. We look forward to working with the EPA this year to continue to increase the volumes of domestically produced biodiesel, renewable diesel and other advanced biofuels.

Specifically we will be working with the Administration to grow the Biomass-based Diesel program from the 2.0 billion gallons established for 2017, and the Advanced Biofuels program from the 3.61 billion ethanol-equivalent gallons the EPA set for 2016.

The evidence clearly shows that stable, growing biodiesel volumes will help achieve the goals of Congress and the EPA. We believe biodiesel is the cleanest fuel available on a commercial-scale today. According to EPA calculations, which were recently corroborated by similar findings from the California Air Resources Board, biodiesel reduces greenhouse gas emissions by 57 percent to 86 percent when compared to petroleum diesel. It is without question the most successful Advanced Biofuel to date under the RFS, and it has delivered the vast majority of Advanced Biofuel under the program.

Additionally, thanks to the market dynamics of the RFS, biodiesel blends are often available on the market at prices lower than petroleum diesel. Fleets across the country, including the U.S. Navy, confirm this.

Yet in the most recent rulemaking, the EPA finalized a 2.0 billion gallon program for Biomass-based Diesel for 2017. That is slightly less than the 2.1 billion gallons of biodiesel actually delivered under the RFS in 2015, and significantly less than the more than 3 billion gallons of registered biodiesel production capacity in the U.S.

We can do more and we should do more, particularly in a 60-billion-gallon diesel market that continues to grow.

After careful review of industry production capacity, feedstock availability and other factors, NBB will continue to urge the EPA to fulfill the intent of Congress and move forward in the growth of Advanced Biofuels and specifically the Biomass-based Diesel program in a meaningful way that drives investment and production.

Of note, we believe the EPA has significantly underestimated the volume of imports that are already making their way into the U.S. Biodiesel imports to the U.S. have grown sharply in recent years. In 2015 alone more than 650 million gallons of biodiesel and renewable diesel were imported to the United States, up from less than 100 million gallons in 2012. We expect that trend to continue. The EPA's decision to streamline feedstock certification for Argentinian biodiesel, in particular, is widely expected to result in significant new volumes of Argentinian biodiesel coming to the U.S. Additionally we anticipate that already mature or growing biodiesel markets from Asia and the European Union will continue to ship product to the U.S. at increasing levels in the coming years.

We believe more robust volume targets are warranted to help accommodate growing imports while at the same time incentivizing domestic production. Clearly, the intent of Congress in developing the RFS—and expanding it under the Energy Independence and Security Act of 2007—was to generate more domestic production of renewable fuels in the diesel markets and to move toward Advanced Biofuels.

While the final EPA volumes established last year were a step in the right direction, NBB believes the agency was still far from fulfilling the intent of Congress. We believe the EPA must provide for meaningful annual increases to effectuate the statute's requirements and goals.

About NBB: NBB is the national trade association representing the biodiesel and renewable diesel industry as the coordinating body for research and development in the United States. It was founded in 1992, and represents fuel producers, feedstock organizations, fuel marketers and distributors, technology providers and other related businesses.

Biodiesel/Renewable Diesel Background: Biodiesel, renewable diesel, and renewable aviation fuels are renewable, low-carbon diesel and jet fuel replacements. The EPA has determined, based on the lifecycle and greenhouse gas emissions requirements established under the Energy Independence and Security Act (EISA) (P.L. 110-140), that these fuels qualify as Advanced Biofuels under the RFS—in that when compared to petroleum diesel, they reduce

greenhouse gas emissions by at least 50 percent. There are over 200 biodiesel and renewable diesel plants registered with the EPA, representing a combined production capacity in excess of 3 billion gallons.

I appreciate the opportunity to submit comments. If you have any questions or comments, please do not hesitate to contact me at 202.737.8801.

Sincerely,
Anne Steckel

Vice President of Federal Affairs National Biodiesel Board

Source: Written Statement of Anne Steckel Vice President of Federal Affairs, National Biodiesel Board. Senate Committee on Environment and Public Works, United States Senate, Oversight of the Renewable Fuel Standard, February 24, 2016.

Birth Control Pill

Oral contraceptives, known as birth control pills, COCP, OC, POP, and most commonly just “the pill,” are generally made up of two synthetically produced forms of hormones that occur in the female body naturally. Synthetic estrogen and progestin (synthetic progesterone) help to regulate a woman’s menstrual cycle. When taken in the appropriate quantities, following a precise timetable, the pill is also very effective in preventing pregnancy. It has shown a 99 percent effective rate: fewer than 1 of every 100 women who uses a birth control pill as a primary contraceptive becomes pregnant. This medical development was more than just a pregnancy preventative; it is noted historically as a seminal step in sexual independence for women, giving them more freedom over their bodies and thus their futures. Thus, oral contraception in the form of a self-administered pill revolutionized birth control options for women and men.

Prior to the development and full-scale release of this contraception form, unwanted pregnancy, religious, and legal barriers were some of the many obstacles to a female’s autonomy over her own body, and even a couple’s enjoyment of sexual intimacy. This medical and social tool is so much a part of American culture that a song by country singer Loretta Lynn in 1975 simply titled “The Pill,” was listed as one of Billboard’s Top 100 country songs.

Today, there are many different kinds of hormonal birth control pills with different levels and types of hormones. Birth control pills are classified as monophasic, biphasic, or triphasic pills (“phasic” meaning by stages or levels), contingent on the amount of hormones released by the pills during the 21 days of a woman’s menstrual cycle. Everything that went into

the pill’s creation and subsequent distribution represents a watershed moment in the history of medicine, women’s issues, sexual freedom, and contraception.

Three pivotal names in the development of the oral contraceptive are Margaret Sanger (1879–1966), Katherine McCormick (1875–1967), and Dr. Gregory Pincus (1903–1967). Margaret Sanger, a staunch supporter of female reproductive rights, helped to underwrite the development of the first birth control in pill form, even raising tens of thousands of dollars for the project. Katherine McCormick, herself holding a BA in biology from MIT and an avid women’s rights activist and philanthropist, helped finance the venture almost singlehandedly. These two dynamic women teamed up with the cutting-edge biologist and scientist Gregory Pincus when, on June 8, 1953, Sanger took McCormick to his small lab outside of Worcester, Massachusetts. With funding from McCormick, in a matter of months, Pincus and his colleagues found that progesterone, which is naturally produced in the body, when used at repeated higher doses on test animals, stopped ovulation.

So, while the use of progesterone was viable as a contraceptive, finding a suitable way to turn it into a pill was not so clear. In what seemed a perfect storm for the creation of the miracle drug, Pincus found that not one but two major drug companies had recently created orally effective forms of synthetic progesterone (progestin). Although birth control as a topic for public conversation and consumption was still very much a sticky subject, both Syntex and Searle laboratories allowed Pincus to use their formulas with his creation and in his initial human studies of the subsequent drug. In 1954, Pincus, along with the well-respected and well-known fertility specialist Dr. John

Rock, successfully conducted the first human trials on 50 women in Massachusetts (Tone 2001).

Additional tests were done outside of the United States, and in 1957, the U.S. Food and Drug Administration (FDA) approved the pill—not as a contraceptive but as an aid for severe menstrual disorders. It was not until 1960 that the FDA approved the first oral contraceptive, Enovid. Dispensing of the pill also required a special effort. David Wagner, an engineer, is credited with designing a dispenser to help his wife remember when and if she had taken her pill. Wagner designed two dispensers similar to those in use today—one circular and one rectangular. While there was initially a bit of copyright infringement as the large drug companies attempted to replicate his design, his model is still predominantly used. The pill was packaged to be dispensed in one of two forms—either for a 21- or a 28-day cycle. For the 21-day distributor, a pill is dispensed daily for three weeks, followed by a week without taking pills. For the 28-pill dispenser, 21 pills are taken, followed by seven days of placebo or sugar pills.

Despite its approval by the FDA, both civil and religious laws prevented its widespread use. Contraceptive use had for many decades been a problematic battleground throughout U.S. history. The biggest opponent was notably the Comstock Law of 1873, which virtually lumped birth control with pornography and prohibited the sale and distribution of birth control, and even materials that mentioned it, throughout the United States. As of 1960, at least 30 states still had Comstock laws in effect. The Supreme Court did not declare the law unconstitutional until 1983, 18 years after the pill had been approved for contraceptive use. Additionally, after the legalization of the use of the birth control pill for the general population, the Catholic Church also took a stance on it when in 1968, Pope Paul VI issued the Church's position paper *Humanae Vitae* ("Of Human Life"). The position piece put forth to followers that the birth control pill was sinful and artificial and therefore not approved by the Church.

Despite this, the pill as a medical tool was quickly embraced by American society. By the end of 1962, an estimated 1.7 million American women were taking Enovid to regulate their cycles and help prevent severe cramping, and curtailing pregnancy as a side effect. After three years, the number almost doubled to 2.3

million. However, in 1964, the pill was still controversial and illegal in eight states. Despite its effectiveness and widespread use, it was not until 1965, with 6.5 million American women on the pill and five years after it had been approved as a contraceptive, that a Supreme Court ruling gave married couples in many states, but not all, the right to use this easy and effective method. In *Griswold v. Connecticut*, the Supreme Court struck down state laws prohibiting contraception for married couples. Nevertheless, it was not until 1972, through the case of *Baird v. Eisenstadt*, that the Supreme Court legalized birth control for all people in the United States whether married or not.

The use of the birth control pill had significant impact beyond controlling contraception. As a result of the autonomy over their reproductive functions, more women attended and graduated from college in the 1970s. The pill is also attributed changes in the socio-moral atmosphere in the United States during the late 1960s and throughout the 1970s. There was an appreciable rise in the rate of single mothers, more unmarried couples were living together, and overt displays of sexuality became more prominent in the media.

The history of the birth control pill in the United States has had many ups and downs. Early in its release, the possibility of thromboembolic disease, which includes blood clots and pulmonary embolism, was recognized and reported in 1961. In 1969, the book *The Doctor's Case Against the Pill* created panic and fear when it was revealed that side effects also included the possibility of heart attack, stroke, depression, weight gain, and loss of sexual desire. Continued inquiries into the safety of this medication resulted in the creation of a lower estrogen dose pill in 1988 and the removal of the original higher-dose pill from the market. This lower dose has been noted to have even more beneficial health benefits, such as a lowered risk of ovarian cancer and pelvic inflammatory disease. Additionally, the estrogen-based pill may have contraindications with certain antibiotics, natural supplements, and antianxiety medications. Nonetheless, the benefits have outweighed the consequences, socially and legally, in the pill's history. By 2000, it became a federal mandate that prescription contraceptives must be covered under insurance offered by employers, no matter the employers' beliefs.

Oral contraception in pill form is no longer as simple as the Enovid first prescribed and approved for public consumption with its 21- or 28-day cycle. The market has grown to include controversial oral contraceptives such as the morning-after pill, also known as Plan B and Seasonale, which limits the number of periods that a woman has per year to four. In addition, oral contraceptives are sometimes prescribed as medication for mild or moderate acne.

D. Chatman-Riley

See also *Vol. 3, Sec. 3: Cancer Research*

Further Reading

“FDA’s Approval of the First Oral Contraceptive, Enovid.” 2009. FDA.gov.

May, Elaine Tyler. 2010. *America and the Pill: A History of Promise, Peril, and Liberation*. New York: Basic Books.

Tone, Andrea. 2001. *Devices & Desires: A History of Contraceptives in America*. New York: Hill and Wang.

Bomb Disposal Robots/Units

Because they are not autonomous, the term “bomb disposal robots” is more of a nickname than a technical name because the devices currently in use are not technically robots. Since their creation in the early 1970s in England, such bomb disposal units have been a key tool for military, law enforcement, and even farming in that they can go into places too dangerous for humans and provide visual feedback as well as often solving situations via remote control.

In 1972, a retired Royal Tank Regiment officer, Peter Miller, created the first bomb disposal unit after the deaths of too many Royal Army bomb defusers during attacks by the Irish Republican Army (IRA). For the main body, he used an electric wheelbarrow and attached a grappling hook controlled by a rope and set of pulleys. The unit’s main function was to tow car bombs to a safe detonation location. Later additions to the device included the ability to shoot a stream of water to short-circuit the bombs.

The reliance on ropes and pulleys proved an early flaw with this unit; later producers used

telecommunication cables, then remote control, and finally a device well known to many millennials—a video game controller. The earlier devices also had traction issues, often falling over while towing vehicles. Dual tank treads or multiple wheels were employed to catch the unit and right it as it tilted.

Currently, the most commonly used remote-control bomb disposal unit in the United States is the Andros. Designed by a subsidiary of Northrop Grumman called Remotec, the unit is used in various fields from military use to law enforcement or special weapons and tactics (SWAT). The Andros has been made into different units, each varying in weight and use. The largest, weighing in at 810 pounds, is the “Wolverine” and is used primarily for military bomb disposal operations. The Andros Mark V-A1 is a variant of the basic model, weighing in at 790 pounds, with four cameras and a manipulator arm. This model notably caught national attention on July 6, 2016, when it was used to kill a suspect who had killed multiple police officers in Dallas, Texas. Instead of defusing a bomb, the robot was deployed to deliver a bomb that detonated in the vicinity of the suspect.

With advancements in computer systems, in the last couple decades, these units have seen the addition of various sensors to show the human controller what the robot sees; radioactive, x-ray, and thermal sensory equipment for different types of bombs; a claw that can move in multiple dimensions to grab objects; wire cutters; drills; and even firearms.

Rosanne Welch

See also *Vol. 3, Sec. 2: Computer/Information Technology; Vol. 3, Sec. 3: Video Game*

Further Reading

Gershgorn, Dave. 2016. “Police Used Bomb Disposal Robot to Kill a Dallas Shooting Suspect.” *Popular Science*. Nov 17. <http://www.popsoci.com/police-used-bomb-disposal-robot-to-kill-dallas-shooting-suspect>, accessed August 31, 2018.

Laska, Paul R. 2015. *Bombs, IEDs, and Explosives: Identification, Investigation, and Disposal Techniques*. Boca Raton, FL: CRC Press.

Brill, Yvonne Madalaine Claeys (1924–2013)

The inventor of a satellite technology that revolutionized satellite systems by boosting fuel efficiency, Yvonne Madalaine Claeys Brill is also known for her contributions to NASA while raising three children.

Brill was born in St. Vital, a suburb of Winnipeg, Manitoba, on December 30, 1924, to Belgian immigrants. When Brill applied to the University of Manitoba's engineering program, there were no accommodations for women at its mandatory outdoor engineering camp, so they were not admitted. Undeterred, Brill studied mathematics and chemistry instead, earning top marks in both programs. Despite the fact that she still lacked an engineering degree, Brill landed a job with Douglas Aircraft in Santa Monica, California. She later earned her master's degree in chemistry at the University of Southern California.

Working with Douglas aircraft and their satellite project, Brill cofounded the Rand Corporation, an early research center and one of the first think tanks for the U.S. Air Force. Here, Brill worked on some of the first satellite designs.

In 1951, she married William Franklin Brill, whom she had met at a talk by famed chemist Linus Pauling. The new couple moved to New Jersey, where Yvonne Brill took a rocketry job at Wright Aeronautical. In 1958, Brill left that company to care for her children but continued working part time as a consultant.

In 1966, Brill returned to work full time at Radio Corporation of America (RCA)'s rocket subsidiary, RCA Astro Electronics. In 1972, she patented a dual-thrust level monopropellant spacecraft propulsion system for satellites, which overhauled satellite propulsion. Previously, electrostatic, or ion, engines would be used after initial takeoff to correct a satellite's flight path to get it into orbit—or perhaps even while the satellite was already in orbit, to maintain its path.

Brill's system used a monopropellant and a manifold system to distribute fuel to different sets of thrusters for different types of thrust, reducing weight and, in turn, improving fuel efficiency. Other names for this system include "hydrazine resistojet" and "electro-thermal hydrazine thruster." This technology is still in

use by almost 120 spacecraft, including satellites that handle worldwide phone service, long-range television broadcasts, and more.

In 1980, *Harper's Bazaar* and the DeBeers Corporation awarded Brill with their Diamond Superwoman award given to women over 40 who had stopped their careers to raise children and then successfully returned. The next year, Brill left the RCA Corporation and joined NASA, where for two years she was manager of the Solid Rocket Motor Program in the shuttle project. In 1986, Brill worked in London at the International Maritime Satellite Organization as propulsion manager for their satellite system.

Though she retired in 1991, Brill continued to consult on propulsion systems of orbiting communication satellites. She served on various panels and boards related to spacecraft technology, including the Mars Observer Spacecraft, which launched in 1992.

In 1986, Brill received the Society of Women Engineers' Achievement Award. She was then elected fellow of the American Institution for Aeronautics and Astronautics and made a member of the U.S. National Academy of Engineering. Brill became an inductee into the Women in Technology International Hall of Fame in 1999, and in 2001, NASA awarded her its Distinguished Public Service Medal. In 2010, she was inducted into the National Inventors Hall of Fame, and in 2011, President Obama awarded Brill the U.S. National Medal of Technology and Innovation. Brill passed away due to complications from breast cancer in 2013.

Eric D. Muro

See also Global Positioning System (GPS); National Aeronautics and Space Administration (NASA); Pauling, Linus "Carl"; *Vol. 2, Sec. 3: Television*; *Vol. 3, Sec. 2: Space Shuttle*; *Vol. 3, Sec. 3: Mars Rover Series*

Further Reading

- Brill, Y. C. 1974. Dual Thrust Level Monopropellant Spacecraft Propulsion System. U.S. Patent 3,807,657, Filed January 1, 1970, and issued April 30, 1974.
- Hargittai, M. 2015. *Women Scientists: Reflections, Challenges, and Breaking Boundaries*. New York: Oxford University Press.
- Martin, D. 2013. "Yvonne Brill, a Pioneering Rocket Scientist, Dies at 88." *The New York Times*, A20.

Primary Document: Yvonne Brill's Patent for New Jet Propulsion Technology (1974)

Yvonne Claeys Brill is famous for two things: engineering for NASA, because she was the first woman to do so, and patenting new jet propulsion technology that is still in use today. Previously, the most attractive method for flight correction in a satellite in orbit was an ion engine, but there were many types of fuel and mechanisms needed in that system that weighed down the satellite and meant less room on it for equipment. Brill invented a new system in 1972 that used the same propellant for all jet propulsion in the satellite from large to small thrusts alike, boosting efficiency and revolutionizing jet propulsion.

United States/Patent I 1191 1111 3,807,657

Brill - [45] Apr. 30, 1974

PROPULSION SYSTEM Attorney, Agent, or Firm—Edward J. Norton; Joseph D. Laza

A flight auxiliary propulsion system for velocity trim, station keeping, momentum adjustment for a space craft comprising rocket or reaction motors, also designated thrusters, utilizing thermally decomposable

monopropellants such as hydrazine and other derivatives, thereof hydrogen peroxide, and isopropyl nitrate. The thrusters are arranged in a distribution or manifold system so that one set of thrusters provides for relatively large thrusts of force in the order of 1 to 5 pounds and another set of low force thrusters in the millipound range. The large thrusts are developed by the catalytic decomposition of the monopropellant into a thrust chamber and through a throat and expansion nozzle to the ambient externally of the spacecraft. The low level thrusts are developed by heating catalytically of thermally decomposed monopropellant by electrical heating elements more commonly known as resisto-jet elements. Dual thrust levels a controllable may also resisto-jet elements. Dual thrust levels may also be achieved by a common motor with a controllable resisto-jet and variable a common throat-area control.

Source: United States Patent Office. Patent I 1191 1111, 3,807,657, Brill—[45] April 30, 1974.

Brown, Marie Van Brittan (1922–1999)

Marie Van Brittan Brown invented the first home security system, which she patented with her husband in 1966. Born in Queens, New York, in 1922, Brown first worked as a nurse. She married Albert Brown, an electronics technician. A combination of her late hours and rising crime in Queens encouraged Marie Brown to think about home security. This problem was exacerbated by the slow response time of police to black neighborhoods in Queens.

Brown devised a system of three peepholes drilled at different heights on a door to meet the different heights of users, from tall adults to small children. A camera, a monitor, and a microphone complemented the peepholes, as did an alarm that connected to the local police station. The camera allowed those inside the home or apartment to see a person outside the door, with the image projected to an in-home monitor not unlike a computer monitor. The microphone allowed those inside the house or apartment to query those outside the door. The system also had a remote-control door latch

that locked or unlocked a door. Marie and Albert Brown called the invention a “Home Security System Using Television Surveillance” and patented it in 1966. Brown never found a commercial manufacturer for it, but her security system is the basis for modern home security systems, and they remain similar to it.

Albert and Marie Brown had two children. They lived in Queens their entire lives. Their daughter Norma emulated her mother and became both an inventor and a nurse. Marie Brown died in Queens, New York, in 1999.

Peg A. Lamphier

See also *Vol. 2, Sec. 1:* Roebeling, Emily; *Vol. 2, Sec. 2:* Cannon, Annie Jump; *Vol. 2, Sec. 3:* Clarke, Edith

Further Reading

Sullivan, Otha Richard, and Jim Haskins. 2009. *Black Stars: African American Women Scientists and Inventors*. San Francisco: Jossey-Bass.

Webster, Raymond B. 1999. *African American Firsts in Science and Technology*. Detroit: Gale.

Bulletproof Vest/Kevlar

Kevlar is a man-made material that consists of a light-weight fiber. It is known for having five times the strength of steel as well as being heat resistant. It is the material used to create body armor, like the bulletproof vest, that is resistant to weaponry while still being light enough to wear. Kevlar was fabricated in 1965 by Stephanie Kwolek (1923–2014), who had been studying chemistry for the DuPont Company. At the time, the company had been looking for a material to replace the steel used to line tires.

Kwolek noticed the strength of polymer structures. A polymer is a substance with a chain-like molecular structure that contains multiple similar units bonded together. Kevlar polymer is synthetically altered so that it can be formed into a straight chain, which is then spun into fibers. The result is an ultra-tough chemical bond. When the fibers are amassed into this material, it has been known to take bullets from point-blank range.

After the creation of the bulletproof vest, Kevlar fabric took the world by storm. Today, it is used in hundreds of products worldwide for protection in industries including motorcycle safety equipment, space programs, commercial airlines, and in naval ships, where it is found in highly durable ropes. Even some clothing has Kevlar for minor protection against cuts and scrapes. Kevlar is directly responsible for saving the lives of tens of thousands of people as well as the development of many new technologies that have made life both safer and easier for the average person. That being said, there is still room for improvement in Kevlar products.

Due to its chemical makeup, Kevlar is often vulnerable to environmental conditions. It absorbs water, which can weigh down wearers; it can also be difficult to compress and cut, and it requires specialty equipment to alter. Pragmatically, the stiffness of the fibers can be uncomfortable to wear and can cause a loss of motion in some circumstances. The result can be dangerous or even fatal for those in situations where they need to be mobile, such as police officers.

Just because Kevlar is stronger than steel does not mean it is invincible. Bulletproof vests made of Kevlar do not protect against blunt-force trauma. If a bullet is

fired into it at point-blank range, it still may do damage, even if it does not penetrate the skin. To prevent injury, some companies are testing combinations of Kevlar with thickening fluids that harden on impact and would absorb the damages that regular Kevlar cannot stop.

Cassady O'Reilly-Hahn

See also *Vol. 1, Sec. 3*: Colt Revolver; Interchangeable Gun Parts; Machine/Gatling Gun

Further Reading

- Nie, Chuanxiong, Zihang Peng, Ye Yang, Chong Cheng, Lang Ma, and Changsheng Zhao. 2016. "Kevlar Based Nanofibrous Particles as Robust, Effective and Recyclable Absorbents for Water Purification." *Journal of Hazardous Materials* 318: 255.
- Sun, Danmei, and Xiaogang Chen. 2012. "Plasma Modification of Kevlar Fabrics for Ballistic Applications." *Textile Research Journal* 82, no. 18: 1928–34.
- Wang, Yan, Zixing Shi, and Jie Yin. 2011. "Kevlar Oligomer Functionalized Graphene for Polymer Composites." *Polymer* 52, no. 16: 3661–70.

Carson, Rachel (1907–1964)

Marine biologist and conservationist Rachel Louise Carson is considered the mother of the American environmental movement. She is best known for her 1962 book *Silent Spring*, which brought the environmental concerns associated with the pesticide DDT to the American public. *Silent Spring* and her other writings are credited with advancing the national and even global environmental movement. The book led to a nationwide ban on DDT as well as other pesticides and inspired a grassroots environmental movement that led to the creation of the U.S. Environmental Protection Agency.

Carson was born in 1907 on a 65-acre farm near Springdale, Pennsylvania. She was an avid reader and writer from a young age. At age 11, she had her first story published. The stories that she read and wrote

mainly had to do with the natural world, particularly the ocean. After high school, she attended the Pennsylvania College for Women, today known as Chatham University. She began her university career as an English student but switched to biology later, though she continued to write for the school's student newspaper and literary supplement. She graduated from the Pennsylvania College for Women in 1929 and then went on to study zoology and genetics at Johns Hopkins in the fall of 1929. She earned a master's degree in zoology in 1932 and had intended to continue for a doctorate, but she was forced to leave Johns Hopkins in 1934 to support her family. In 1935, her father died, leaving Carson to care for her mother. In 1937, Carson's sister, Marian, died. Marian's two daughters went to live with Carson and her mother, making her financial situation even more strenuous.

Carson accepted a temporary position with the U.S. Bureau of Fisheries in 1935 to help with the finances. In 1936, she became the second woman ever to be hired for a full-time professional position for the Bureau of Fisheries as a junior aquatic biologist. Carson rose within the Fish and Wildlife Service and was the chief editor of publications by 1949.

By 1952, Carson had decided to make the transition to writing full time. Her earlier trilogy of novels, *Under the Sea Wing*, *The Sea Around Us*, and *The Edge of the Sea*, began her career as a bestselling author. *The Sea Around Us* was her most critically acclaimed work before *Silent Spring*. The books focused on the life in the ocean and coastal ecosystems. In 1953, she met Dorothy Freeman (1898–1978) after moving with her mother to Maine's Southport Island. Though Freeman was married, the two developed a close emotional bond that endured until Carson's death. The same year that she met Freeman, Carson adopted Roger Christie after his mother, one of her sister's daughters, died.

Silent Spring was published in 1962. Carson had been interested in how pesticides were affecting the environment since the 1940s because of the recent decline in the bird populations and the Great Cranberry Scandal of 1957, when cranberries were found to contain high levels of the herbicide aminotriazole. She was in the middle of her work on *Silent Spring*



Rachel Carson, seen here reading in her backyard, sounded the alarm for climate change in 1962 in her book *Silent Spring*. She is credited with jump-starting the environmental movement and helping found Earth Day. (Alfred Eisenstaedt/The LIFE Picture Collection/Getty Images)

when she learned that she had multiple cysts in her breasts, which necessitated a mastectomy. By December 1960, Carson had discovered that the tumor was in fact malignant and the cancer had metastasized. Her illness made her work on *Silent Spring* all the more difficult. The book was published first in serialization in *The New Yorker*. This, coupled with the fact that the book was selected for the Book of the Month, meant that an unprecedented number of Americans were exposed to environmentalism for the first time.

The book was not without critics. The chemical industry that made pesticides, backed by conservative politicians and organizations, attacked her for hampering industry and agribusiness. The attacks on Carson

and her work were so vehement that they eventually backfired. The book inspired grassroots environmental activism and eventually the phaseout of DDT and other dangerous chemicals. The Environmental Protection Agency was also created because of some of the concerns that Carson brought out to the public in *Silent Spring*.

Weakened by cancer and radiation therapy, Carson died of a heart attack in 1964 in her home in Silver Spring, Maryland. Today, Carson's work is seen as the basis for the modern environmental movement and ecofeminism.

Moriah Saldana

See also Vol. 3, Sec. 3: Grandin, Temple

Further Reading

Carson, Rachel. 1962. *Silent Spring*. New York: Houghton Mifflin.

Lear, Linda. 2009. *Rachel Carson: Witness for Nature*. Boston: Houghton Mifflin Harcourt.

Michals, Debra. 2015. "Rachel Carson." *Biographies*. National Women's History Museum.

Sideris, Lisa H., and Kathleen Dean Moore. 2008. *Rachel Carson: Legacy and Challenge*. Albany: State University of New York Press.

Chlorofluorocarbons (CFCs)

Chlorofluorocarbons (commonly known as CFCs) are a class of organic compounds containing carbon, chlorine, and fluorine. First discovered in the 19th century, they were used widely during the 20th century in a number of industrial and consumer applications (such as refrigeration and aerosol propellants). After the discovery that these gases were breaking down the planet's ozone layer, their manufacture was discontinued.

The first chlorofluorocarbons were synthesized in the late 19th century by the Belgian chemist Frédéric Swarts, but it wasn't until the 1920s that chemists realized the commercial applications of CFCs. A research team at General Motors headed by chemist Thomas Midgley, who also invented leaded gasoline, invented a new chlorine-based refrigerant that GM began manufacturing in 1930 under the name "Freon."

Freon is nonflammable, stable, and less toxic than refrigerants like ammonia. It rapidly became the most popular refrigerant chemical in consumer use. Other CFCs became popular for their ability to produce foam in insulation and packing materials, as cleaning solvents for electronics, and as aerosol propellant after the invention of the aerosol spray can in 1941. As refrigerators, automobiles with air-conditioning, aerosol cans, and other CFC applications became more popular, CFC production rose from less than 100,000 tons in 1950 to nearly a million tons in 1974.

In that year, chemists F. Sherwood Rowland and Mario Molina of the University of California, Irvine announced that chlorofluorocarbons could rise slowly into the upper atmosphere, where they would react with the atmosphere's ozone layer and break it down. The chlorine in CFCs reacts with ozone to create chlorine monoxide, which itself breaks down. A single chlorine atom in the ozone layer destroys 100,000 ozone molecules. The chemists further declared that at current production levels, CFCs would destroy about 10 percent of the ozone layer within a century. The ozone layer absorbs as much as 99 percent of the ultraviolet light reaching the earth from the sun. The loss predicted by Rowland and Molina would render the earth's surface virtually uninhabitable for most of the life-forms exposed to sunlight.

By the end of the year, public awareness of this announcement was growing, and within a year, aerosol can sales were down 25 percent. Despite intense lobbying, in May 1977, the Environmental Protection Agency and other U.S. government agencies ordered CFC manufacturing to halt in the United States by the end of 1978. The early successes for the anti-CFC movement sputtered out, however, as industrial firms began pushing back, especially after a Republican administration took office in 1981.

By 1986, CFC production had reached a new height of over 1.2 million tons of annual production. By this point, the scientific consensus on CFC production was great enough to overwhelm many other political considerations. In 1985, 20 nations signed the Vienna Convention, which established the groundwork for an eventual ban on CFCs. That same year, it was discovered that the ozone layer over Antarctica had diminished by over two-thirds. The "ozone hole"

dramatically showed that ozone depletion was a real threat to human and indeed to all life.

In 1987, an international conference in Montreal led to the ratification of the Montreal Protocol, which committed every nation in the world to reduce CFC production by half by 1998 and to completely cease new production by 2000. Later meetings sped the final phaseout date up to 1996. Follow-up meetings led to commitments to phase out a related class of chemicals, hydrochlorofluorocarbons. The Montreal Protocol was extremely successful; ratified by every nation on earth, it has also been adhered to with remarkable strictness. Only a small amount of CFCs were manufactured after 1996 for medical and research purposes; the medical exemption ended in 2008. It is now predicted that the ozone layer will return to its former size sometime after 2050.

James L. Erwin

See also Agent Orange; Climate Change

Further Reading

Benedick, Richard Elliot. 1988. *Ozone Diplomacy: New Directions in Safeguarding the Planet, Enlarged Edition*. Cambridge, MA: Harvard University Press.

Roan, Sharon. 1990. *Ozone Crisis: The 15-Year Evolution of a Sudden Global Emergency*. New York: Wiley Science Editions.

Climate Change

Climate change (or global warming), a controversial issue, is widely considered by the scientific community to have been caused by the use of industrial technology, yet technological innovations may hold the key to addressing its environmental challenges. Even though the societal debate on the cause (or causes) of climate change is far from over, the prevailing view of policy makers has been that humanity has caused negative climate change and therefore, it is our responsibility to fix the problem.

Both surface and satellite temperature readings have confirmed that the average temperature of the earth has risen in the last two centuries. In fact, the

warmest five-year period on record was 2011 to 2015. However, the identification of the cause (or causes) of the climate change have remained controversial. Most scientists believe that human activity, most notably the burning of fossil fuels since industrialization in the 1800s, is to blame. However, a small minority has maintained that just because industrialization and global warming happened during the same time frame does not prove that one caused the other. In fact, Earth data from the past 600,000 years reveals a pattern of rising temperature before carbon increases—not after. These scientists also maintain that the earth’s climate is too complex (with too many known and unknown variables) to rule out natural causes as the main driving forces behind climate change.

In 2007, former vice president Al Gore was awarded the Nobel Prize for his efforts to convince the public that climate change is man-made. In *An Inconvenient Truth*, a 2006 documentary film, Gore stated that global warming was melting the polar ice caps at such a rate that water levels could rise by 20 feet by the next century, leaving parts of the United States under water. In 2009, hackers posted excerpts of online of e-mails and data from climate scientists working at one of the most respected and influential climate science research institutions in the world, the University of East Anglia’s (UEA) Climate Research Unit in Norwich, England. The “Climategate” excerpts gave the impression that scientists might have manipulated certain data to support evidence of global warming. Conspiracy theorists speculated on a possible motivation for this type of deception: researchers need funding, and only researchers who identify problems that need to be fixed get it. However, in 2010, a review group of scientists from many countries concluded that, in spite of some errors, UEA’s conclusions about climate change were sound.

In spite of disagreements and controversies, most world leaders have accepted the interpretation of human-caused climate change. According to this view, the negative side effects of climate change have included droughts, floods, and other severe weather. Most of the carbon dioxide in the atmosphere is pumped out by factories. Over the years, developing nations have attempted to catch up to developed nations in an attempt to improve living standards for their people by

building and running factories. Consequently, in spite of environmental concerns, most developing nations have opted to ignore emission restrictions.

The United States ranks as one of the biggest air-polluting developed nations in the world. According to the U.S. EPA, in 2014, carbon dioxide accounted for 81 percent of greenhouse gas emission in the country, and American industries, including farming and electricity production, accounted for 60 percent of all air pollution. Even though most American pollution is caused by industry, the American trend has been to prioritize public initiatives usually driven by assurance in the ability of new technologies to solve problems.

Since most energy plants run on fossil fuel, environmental campaigns have attempted to convince Americans to use less energy. In this regard, policy makers have promoted the construction of energy-efficient homes with energy-efficient lightbulbs and energy-efficient appliances. A negligible percentage of Americans have made the switch to clean energy sources, including the use of solar and wind energy, to run their homes. Automakers have made various types of “green” automobiles. A growing percentage of Americans have purchased automobiles that run on alternative fuel such as natural gas (which produces less carbon dioxide than gasoline) or hydrogen (which produces no carbon dioxide).

Since the 1980s, automakers have sold more popular flexible-fuel vehicles that run on a gasoline-ethanol blend. However, ethanol has produced far fewer advantages than advertised. Ethanol is usually produced from corn, and the tractors that are used to plant and harvest it burn fossil fuels. In like manner, the large trucks that transport ethanol to gas stations burn fossil fuels. In the meantime, American industries continue to account for most American-produced carbon dioxide. Although technological innovations have produced alternative energy sources—including hydroelectric dams, which capture energy from moving water; geothermal plants, which use heat from deep inside the earth to generate steam to make electricity; and wind turbines, which use the natural air flow to produce energy—most American industries continue to burn fossil fuel.

On the world stage, two cutting-edge technologies to aid humankind in fighting human-caused climate

change have been proposed: carbon capture and storage (CCS) and solar radiation management. The CCS system separates carbon dioxide from other gases that are emitted from a factory and then funnels the carbon dioxide through a pipeline (or transports it by ship). The gas is then deposited miles below the planet’s surface. However, as of 2015, CCS was still too expensive to be practical, and it had only been tested at a handful of sites. Solar radiation management is a theoretical concept. The idea is to mimic the natural phenomenon that occurs after volcanic eruptions as sulfur spewed into the atmosphere blocks sunlight; that is, to replicate the phenomenon by spewing aerosols into the sky that would then reflect the sun’s rays away from earth and into space, giving the earth an artificial sunscreen. However, most scientists are hesitant to deploy such a method, because there is no way of knowing what it might do to the earth’s complex climate system.

In 1997, representatives from more than 100 nations met at Kyoto, Japan, to negotiate the first international climate change agreement. The Kyoto Treaty required industrialized nations to cut their greenhouse emissions by 5 percent below 1990 levels by 2012. On the other hand, the treaty did not restrict emissions in developing nations (including China). Although the treaty had initial support from President Bill Clinton, the U.S. Senate rejected it by a vote of 95–0. China and the United States were the two nations most responsible for greenhouse emissions. With these two nations out of the agreement, the treaty lost momentum. It took eight years for participating countries to ratify the treaty in 2005. However, by 2011, some participating nations, including Canada, Russia, and Japan, abandoned the treaty. Critics assessed that the treaty had been a failure. However, more optimistic activists viewed the treaty as a critical first step. They pointed out two important accomplishments of the treaty: it had led to the creation of the first international system for monitoring emissions, and it had encouraged nonparticipating nations to pass their own emission laws. As 2012 approached, some participating nations, including Peru and Djibouti, agreed to extend the agreement to 2020. However, by 2014, only 17 out of 144 nations needed for ratification of the extension had signed.

Building on lessons learned from the Kyoto Treaty, in 2015, leaders met in Paris, France, and signed an agreement to reduce the buildup of greenhouse gases. Leaders from developing nations asked leaders from developed nations to help pay for floods and droughts. On behalf of the United States, President Barack Obama donated a \$500 million grant to the Green Climate Fund to help developing nations that were committed to agreement. By 2016, the United States and China were responsible for 40 percent of global emissions. Although neither of the two nations signed the Paris Agreement, they promised to sign it at some time in the future. In all, 196 nations adopted the agreement to limit global warming to the relatively safe level of 3.6°F (2°C). In 2016, four world cities—Paris, Madrid, Athens, and Mexico City—announced they would ban diesel vehicles by 2025.

Rolando Avila

See also Hydrogen Energy; *Vol. 1, Sec. 3: Coal-Mining Technologies*; *Vol. 3, Sec. 2: Nuclear Energy/Nuclear Power Plants*; Solar Energy; Wind Energy

Further Reading

- Bolin, Bert. 2008. *A History of the Science and Politics of Climate Change: The Role of the Intergovernmental Panel on Climate Change*. New York: Cambridge University Press.
- Dessler, Andrew Emory, and Edward Parson. 2006. *The Science and Politics of Global Climate Change: A Guide to the Debate*. Cambridge: Cambridge University Press.
- U.S. Environment Protection Agency. 2014. *Climate Change Indicators in the United States, 2014*. 3rd ed. EPA 430-R-14-004-R-14-004. <https://www.epa.gov/sites/production/files/2016-07/documents/climateindicators-full-2014.pdf>, accessed September 25, 2018.

CO₂ Welding

Welding is a fabrication process in which two materials are joined by fusion. There are various forms of welding, including oxy-fuel welding, arc welding, and others. In 1953, Lyubavskii and Novoshilov invented CO₂ welding. CO₂ welding became so popular because

it was one of the more affordable ways to weld, which made it preferred for welding steels.

Tools showing signs of forge welding (heating metals and pounding them together) can be found as early as the Bronze and Iron Ages, particularly in Europe and the Middle East. In 1800, two men, one English, the other Russian, nearly simultaneously invented electrical arc welding. Advances in this type of welding occurred throughout the 19th century. In the late 1800s, gas welding was invented, though arc welding was far more popular. Nonetheless, the discovery of gas fuel welding was a key step for the invention of CO₂ welding.

CO₂ welding is where the wire used to weld, wound into a coil, is fed into the welding torch automatically by a motor. The welding wire reacts, becoming electrified through the contact tip, which then becomes the electrode that strikes an arc between itself and the base metal. The arc heat melts that piece of welding wire and the base metal, joining pieces of base metal together. To prevent the weld metal from being affected by oxygen and nitrogen in the air, CO₂ gas is used to shield the weld pool. The CO₂ is provided from the nozzle of the welding torch.

CO₂ is the prevalent reactive gas used in welding because it is the only gas that can be used in its purest form without having to add an inert gas. An inert gas has very low reactivity with other substances. The use of fewer gases is less expensive. There have been many advancements in CO₂ welding, including the introduction of electrode wires with smaller diameters, which makes it more convenient to weld thinner material. This innovation led to the short-circuit variation, which includes micro-wire welding, short-arc welding, and dip-transfer welding.

Jesus Salas

See also Plasma Arc Welding; *Vol. 1, Sec. 2: Gas Tungsten Arc Welding*; *Vol. 2, Sec. 2: Welding, Alternating Current*

Further Reading

- Das, Biswajit, and Dipanker Bose. 2014. *Optimization of Process Parameters of MIG-CO₂ Welding Process*. Saarbrücken, Germany: Lambert Academic.
- Smith, A. A. 1970. *CO₂ Welding of Steel*. 3rd ed. Cambridge: Welding Institute.

Commodore 64

The Commodore 64 (C64) computer was introduced in January 1981 by Jack Tramiel, the president of Commodore International. The Commodore 64 became one of the bestselling computers in history because it was significantly more affordable and powerful than any other personal computer on the market at the time.

Though the C64 was originally planned as a video game console, the company expanded plans for the personal computer to replace an older product line. Commodore kept costs down by manufacturing the integrated circuit design and random access memory (RAM) chips in-house. Commodore's competition came primarily from the equally revolutionary Apple II. The two computers represented different approaches to personal computing. The Apple II featured an open architecture system that allowed for upgrades, whereas the C64 was a closed system with a number of ports that allowed for plug-ins like external drives, printers, and modems.

Manufactured from 1982 to 1992, the C64 was on the forefront of the personal computer revolution of the late 20th century.

Jesus Salas

See also Atari; IBM 360 Computer; Integrated Circuit; Intel Corporation; *Vol. 3, Sec. 2*: Apple; Apple II; IBM Personal Computer

Further Reading

Jarratt, Steve, and Sam Dyer. 2016. *Commodore 64: A Visual Compendium*. Expanded ed. Bath, UK: Bitmap Books.

Leemon, Sheldon. 1987. *Mapping the Commodore 64 & 64C*. n.p.: Compute.

Computerized Telephone Switching.

See Telephone Switching, Computerized

Comsat/Intelsat

Comsat is a global telecommunications company designed to provide satellite communication services approved by the Communications Satellite Act of

1962. This Act allowed the commercialization of satellite communications in cooperation with other countries. When President John F. Kennedy signed the Act in direct response to the success of the Russian satellite program, it created a new, private company to develop and operate the planned global satellite system. Comsat then became first commercial satellite system operating in the private sector.

Two years later, Comsat contracted Hughes Aircraft Company, founded by inventor Howard Hughes (1905–1976), to design and create its first operational satellite. Known first as Early Bird and later as Intelsat I, engineers designed this satellite for geosynchronous orbit, or the ability to follow the rotation of the earth and in a fixed position over a particular location on the surface.

The success of Comsat nudged the creation of a new private company, Intelsat (International Telecommunications Satellite Consortium), in August 1964. Including 15 allied countries, this multinational organization represented all their interests and became the main source of income for Comsat in the decades to follow. Comsat was the U.S. representative of Intelsat and was selected as manager of Intelsat on behalf of the 15 countries involved.

In April 1965, Intelsat I launched, traveled over 22,000 miles above the earth, and took a permanent position in geosynchronous orbit above the coast of Brazil, making live television broadcasts available across the Atlantic and increasing international telephone capacity by nearly two-thirds.

Comsat then connected satellite coverage between the United States and Europe and looked toward providing full global coverage. A month after Intelsat I was launched, the Federal Communications Commission tasked Comsat with constructing and operating earth stations to broadcast information for international communications.

In 1965, effort was underway to begin the development of the second generation of Intelsat satellites, the Intelsat IIs, intended to provide communications support for NASA's Apollo program. A year later, Comsat experienced its first major setback when the first Intelsat II satellite failed to reach geosynchronous orbit. The second launch in 1967 succeeded in creating the first full satellite coverage over the Pacific

Ocean. In 1968, Comsat began producing Intelsat III, and in 1969, one of the Intelsat III satellites successfully placed in geosynchronous orbit over the Indian Ocean marked the first time that humanity had connected the entire globe with full satellite coverage.

During the 1980s, Comsat entered the entertainment industry through the use of fiber-optic networks. Many cable networks had used ground-based networks instead of satellite networks, and this threatened Comsat's primary business, which was transmitting television media through satellites. This made the need to diversify its services more apparent, leading to Comsat acquiring a majority ownership of the Denver Nuggets.

Comsat entered the 1990s owning three primary business types: international communications, technology services, and entertainment. Today, Comsat and its industry partners include the U.S. military, which now leases satellites from Comsat.

Rosanne Welch

See also Apollo Project; Satellites and Space Probes

Further Reading

- McLucas, John L. 2012. *Reflections of a Technocrat: Managing Defense, Air, and Space Programs during the Cold War, National Reconnaissance and NRO, Commercial Space Programs, Comsat*. Washington, D.C.: World Spaceflight News.
- Whalen, David. 2014. *The Origins of Satellite Communications, 1945–1965*. Washington, D.C.: Smithsonian History of Aviation and Spaceflight Series.
- Whalen, David. 2014. *The Rise and Fall of COMSAT: Technology, Business, and Government*. London: Palgrave Macmillan.

Curanderas

Curanderas are female spiritual healers of Latin American descent who practice faith and bodily healing in rural and working-class areas of North and South America. *Curanderismo*, or faith healing, has a long history stemming from indigenous Latin American healing practices, Judeo-Christian beliefs, Hispano-Arabic philosophies, and Western medical traditions.

While practitioners of *curanderismo* can be male or female, *curanderas* specifically function as cultural matriarchs for Latino communities, especially in the United States.

Curanderas work under the assumption that spiritual unease can manifest as physical ailments and believe that the power to heal is a gift from God. They are often sought out by patients who are poor, uninsured, or undocumented and those who have not found success in alleviating their symptoms through traditional Western medicine, distrust Western health care workers, or believe that there are supernatural causes for their illnesses. Though traditionally, patients are not charged for treatments, many give thanks by donating food, clothing, and housewares.

The *curandera* believes in prayer and her own touch, along with herbs, fruits, flowers, and oils for traditional healing rituals. As central figures in their communities, *curanderas* are able to diagnose their patients based on information gathered about family relationships and the social lives of their patients, including guilt stemming from perceived sins or immoral actions. Often, patients from religious Spanish-speaking communities are more forthcoming with a healer who shares a similar cultural, religious, and linguistic background, thereby allowing *curanderas* to gather more information about the lives of their patients than medical practitioners from non-Latino communities.

Curanderas diagnose patients after a physical exam and spiritual consultation, after which treatments are commonly a mixture of prayer, psychological discovery, physical therapy, and herbal remedies. The *curandera* treats all aspects of mental, physical, and spiritual life of a patient through communal knowledge of the person's medical and psychological history, thereby focusing on the totality of a patient's needs and striving to achieve balance in the patient's life.

Curanderas often discover their ability to heal at a young age. Through a system of mentoring under an older established *curandera*, a girl or young woman apprentices to learn the healing trade. Because *curanderismo* is not a static philosophy, *curanderas* establish their own style of healing, incorporating philosophies of multiple religious and medical traditions. Some *curanderas* attend nursing school; study Eastern traditions, such as yoga and acupuncture; or



A curandera moves a chalice of burning herbs to cleanse the aura of a customer at Botanica Cristy in Santa Ana, California. The curandera uses prayer and her own touch along with herbs, fruits, flowers, and oils for traditional healing rituals. (Don Bartletti/Los Angeles Times via Getty Images)

specialize in herbal healing (*yerbera*), massage therapy (*sobadora*), or midwifery (*partera*).

A successful *curandera* can achieve prominence in her community for her ability to cure patients through natural alternative means and by performing spiritual cleansings, or *limpias*. If a *curandera* cannot diagnose natural causes for ailments in a patient, then she will try to treat supernatural causes. This belief in “magic” is central to *curanderismo*, and diagnoses range from sins a patient may have committed to the work of black magic by a witch (*bruja*). In this way, the *curandera* is believed to be a practitioner of white magic, and as God’s vessel, she works on the side of good. She acts as a bridge or translator between the patient and the voice of God. As such, a patient is expected to trust in the diagnosis of the *curandera* and actively participate in the treatment through healing rituals that involve atoning for sins and carrying out

acts of forgiveness, sacrifice, and self-discipline. While skeptics focus on this magical aspect of healing as a way of undermining faith healers, it should be noted that *curanderas* often view their healing as complementary to traditional medicine, not exclusive from it. By focusing on overlapping treatments that appeal to the cultural sensibilities of their patients, *curanderas* are able to treat their clientele with a variety of therapies.

Curanderismo is a cultural aspect of Latino communities largely unknown to majority American culture. Eurocentric representations of *curanderas* often trivialize the spiritual healing philosophy by focusing on the superstitious elements or depicting *curanderas* as greedy folk healers preying on desperate members of an ignorant community. The fact that *curanderas* are women does little to enhance their cultural power. Nonetheless, the majority of *curanderas* spend most

of their lives studying their craft and are powerful members of their communities.

Wendy Braun

See also *Vol. 1, Sec. 2:* Blackwell, Elizabeth; *Vol. 1, Sec. 3:* Civil War Medicine

Further Reading

- Anaya, Rudolfo. 1972. *Bless Me, Ultima*. Berkeley, CA: TQS.
- de la Portilla, Elizabeth. 2009. *They All Want Magic: Curanderas and Folk Healing*. College Station: Texas A&M University Press.
- Hunter, Leslie Gene, and Cecilia Aros Hunter. 1996. “‘Mother Lane’ and the ‘New Mooners’: An Expression of ‘Curanderismo.’” *Southwestern Historical Quarterly* 99, no. 3: 291–325.
- Perrone, Bobette, H. Henrietta Stockel, and Victoria Krueger. 1993. *Medicine Women, Curanderas, and Women Doctors*. Norman: University of Oklahoma Press.

Dark Matter Science

Dark matter science arose because of observations of the universe made in the 1930s with light telescope technology. Dark matter, an invisible matter, was detected by the effects (gravitational force) it had on visible material. Although some astronomers initially resisted the idea of dark matter, later observations made during the telescope technology revolution of the 1970s confirmed its existence. However, further investigations were needed to identify its nature. Although the answer to this question remained elusive, scientists seriously considered many theories as new observations of the universe revealed more of its dynamics. With the use of the Hubble Telescope in the 1990s, scientists concluded that dark matter alone was not sufficient to explain the behavior of the universe. They theorized that dark energy (another unknown entity) interacted with dark matter and the visible universe. However, due to the vastness and complexity of the universe, new discoveries often led to new mysteries. Perhaps these mysteries can be solved (or better understood) with future telescope technological innovations.

During the early 1930s, Dutch astronomer Jan Oort (1900–1992) and Swiss astronomer Fritz Zwicky (1898–1974) discovered that most of the mass in the universe did not generate light and was “hidden from view.” In 1932, Oort studied the motion of stars in the Milky Way galaxy. He observed that stars moved at high velocities around the center of the galaxy, but they did not break away from it. Scientists believed that all objects with mass generated gravitational pull, and this pull kept the galaxy together. Greater mass meant greater pull. The opposite was equally true. However, Oort calculated that the mass required to keep the galaxy intact could not be accounted for by its visible matter. The next year, Zwicky studied the motion of galaxies within the Coma cluster (which contains more than 1,000 identified galaxies). He concluded that the cluster should have spun apart billions of years ago, because its visible mass could not explain how these bodies were held in their respective orbits. Oort called the invisible mass, “hidden matter.” Zwicky called it “dark matter.”

In 1940, American astronomer Horace Badcock (1912–2003) studied the Andromeda galaxy (the Milky Way’s closest neighbor) and confirmed the dark matter phenomenon. However, some scientists denied these findings, and they speculated on other possible explanations. For example, perhaps other gravity-producing objects were, in fact, present and emitting light but were obscured from the light telescopes of that time due to interstellar dust clouds. A scientific revolution in telescope technology, however, settled the debate during the 1970s. Digital-imaging intensifiers made it possible for astronomers to confirm the existence of dark matter. Later, other new technologies allowed astronomers to make observations across several portions of the light spectrum (including radio, infrared, ultraviolet, and x-ray). These technological developments allowed scientists to rule out dust cloud obstructions. In fact, x-ray telescope technology allowed astronomers to confirm that even dust clouds were held together by some unknown gravitational pull.

By the 1990s, scientists had reached a consensus over the existence of dark matter, and research included investigations into its nature. There were several leading theories. According to the massive compact halo objects (MACHOs) theory, the unaccounted-for matter was

composed of many commonly known objects that did not shine. For example, some objects could be too small to reflect light far enough to be seen from Earth. Some larger objects, like planets, may be too far from stars to reflect light. Even the largest objects, like black holes and brown dwarfs (substellar objects that never ignite fusion reactions), may be present but unseen. However, according to the weakly interacting massive particles (WIMPs) theory, unseen matter was not composed of “normal” (or commonly known) objects. This theory referred to “exotic” forms of matter that had not yet been directly observed. Instead, dark matter was only detectable by the way it interacted with visible objects. Although both theories were popular in dark matter science, some scientists found the MACHOs theory problematic. First, few small objects had been found after more than a century of searching, which had led scientists to believe that insufficient small objects existed to account for the massive gravitational properties of dark matter. Second, during the Big Bang (the most widely accepted theory regarding the origin and initial evolution of the universe), the universe was very hot, and the majority of small objects would have been fused together to produce heavier ones. For these and other reasons, some scientists preferred the WIMPs theory.

During the 1990s, astronomers gained access to Hubble, the first large space telescope, which orbited Earth. Over the years, Hubble produced high-quality, never-before-seen images of the universe. Through the use of the technologically advanced equipment, scientists found that the universe was expanding at a tremendous rate of speed. The revelation seemed to be at odds with the accepted properties of dark matter, which was believed to keep galaxies and the entire universe intact. After the discovery of universe expansion, scientists were forced to reconcile their understanding of the properties of dark matter with those of dark energy, a new, unknown force. Dark matter, then, was described as an unknown extragravitational force that held galaxies together (like glue) as they spun at great speeds, while at the same time, dark energy pushed each intact galaxy outward from the center point of the Big Bang (like dots painted on the surface of an inflating balloon).

Dark energy was an even greater mystery than dark matter. For one thing, known physical laws dictated that universe expansion should have been slowing

down over time to a stop, and then the material of the universe should contract back to the point where the Big Bang originated (like the way a ball that is thrown in the air stops and then returns to its point of origin). However, the universe was not only defying this law of gravity, but its expansion appeared to be gaining speed. Scientists theorized that there might not be sufficient dark matter in the universe to halt its expansion, but they could not explain why expansion was accelerating. If acceleration continued, which seemed to be the case based on observations and calculations, the ultimate fate of the universe was known. Accelerated expansion would eventually disperse all galaxies beyond Earth’s light horizon, leaving the Milky Way galaxy surrounded by only the cold darkness of space.

By the 2000s, new technologies enabled scientists to confirm that dark matter did not pervade space uniformly or independently of other visible structures. Instead, its presence was concentrated in and around galaxies. By 2001, scientists had detected supermassive black holes in the center of some galaxies. Further observations in 2004 with the Very Long Baseline Array (VLBA), which was made up of 10 radio telescopes located across the United States, confirmed the presence of a large black hole (about the size of Earth’s orbit around the sun) at the center of the Milky Way. The discoveries led some scientists to believe that black holes may have supplied some (but not all) of the gravitational pull needed to keep galaxies together. Another theory centered around neutrinos (invisible subatomic particles) that scientists believed existed in great numbers in the universe. In the late 1990s, they discovered that neutrinos had mass. Consequently, some physicists theorized that the enormous number of neutrinos in the universe might account for the unexplained gravity. However, in 2002, new calculations showed that the collective mass of all neutrinos could only account for a fifth of the dark matter in the universe. After further study, scientists theorized on the makeup of the universe: 5 percent ordinary matter, 23 percent dark matter, and 72 percent dark energy. In other words, only 5 percent of the entire universe was visible to Earth and was composed of recognizable objects. The rest (95 percent) was a mystery.

Finally, in recent years, some scientists have been fascinated with how dark matter and dark energy seem

to be interchangeable. Dark matter pulls material together while dark energy pushes material away (like a magnet that can pull material toward it but also repel another magnet).

Without a doubt, new telescope technologies have revealed new aspects of the universe, but the revelations have often led to deeper mysteries. Perhaps another scientific revolution in observation technology (like the one that occurred in the 1970s) may be necessary to reach another breakthrough in dark matter science.

Rolando Avila

See also National Aeronautics and Space Administration (NASA); Space Science and Technology

Further Reading

“Dark Energy, Dark Matter.” National Aeronautics and Space Administration. science.nasa.gov/astrophysics/focus-areas/what-is-dark-energy, accessed August 31, 2018.

Freeman, Kenneth C. 2006. *In Search of Dark Matter*. Berlin, Germany, and New York: Springer.

Krauss, Lawrence M. 1989. *The Fifth Essence: The Search for Dark Matter in the Universe*. New York: Basic Books.

Panek, Richard. 2011. *The 4 Percent Universe: Dark Matter, Dark Energy, and the Race to Discover the Rest of Reality*. Boston: Houghton Mifflin Harcourt.

Dolby Laboratories

Based in San Francisco, California, Dolby Laboratories develops audio and visual technologies for use by industries such as film, video games, and music. Today, Dolby Labs is known for its work with surround sound, which is played from all directions instead of a single one. The company’s Dolby Digital product is an audio compression technique that brought surround sound to cinemas and later to home theaters, speaker systems, and other setups. Dolby Digital would later be adopted as part of the standards for DVD, Blu-ray, and broadcast systems, and even for video games and their associated systems.

Dolby Laboratories was founded in London, England on May 18, 1965, by Ray Dolby (1919–2013). It

moved to San Francisco in 1976. The company’s first products involved noise reduction systems such as the Dolby A, which was intended for professional recording studios. Studios welcomed Dolby A, as many of them were transitioning to multitrack recording in hopes of reducing loss of sound detail and depth. Dolby A would become commonplace among studios after multitrack recording became the standard.

Their focus on noise reduction systems meant that Dolby technologies were eventually used to improve audio quality in films. One of the first films to utilize its technologies was *A Clockwork Orange* (1971). Dolby Laboratories also developed a stereo sound system called Dolby Stereo, which was first used in the film *Lisztomania* (1975). Though stereo sound was not a new concept at the time, mono sound was still the standard: most recordings only utilized one channel of sound. Stereo sound allowed for more channels, but it was adopted widely by cinemas only after Dolby Stereo was used in the recording of the megahit film *Star Wars* (1977).

Dolby Stereo was then followed by Dolby Stereo Digital, later rebranded to Dolby Digital. This surround sound system was first used in *Batman Returns* (1992) and became popular in both the cinema and home after it was adopted as part of the standards for DVD. Dolby Laboratories followed it with Dolby Surround 7.1 and Dolby Atmos. The former was used first in *Toy Story 3* (2010) and the latter in *Brave* (2012). Today, these formats are now slowly being adopted for use in home theaters. Dolby Laboratories released a projection system called Dolby Vision in 2014 and followed it with the introduction of a new cinema format, Dolby Cinema.

Alexandria Beatrice E. Vinuya

See also Vol. 2, Sec. 1: Motion Picture Camera; Vol. 2, Sec. 2: Radio; Talking Movies; Vol. 2, Sec. 3: Electric Guitar; Vol. 3, Sec. 2: CD and DVD; Vol. 3, Sec. 3: MP3

Further Reading

Lastra, James. 2000. *Sound Technology and the American Cinemas*. New York: Columbia University Press.

Taylor, Timothy D., Mark Katz, and Tony Grajeda. 2012. *Music, Sound, and Technology in America: A Documentary History of Early Phonograph, Cinema, and Radio*. Durham, NC: Duke University Press.

Drones

Drones are also known by the moniker “unmanned aerial vehicles,” which points out the basic concept behind them. These tools do not require a person on board to serve as pilot and, as such, they can strike targets at a distance. Modern drones use computer inputs to achieve their targets and strike zones.

The first testing and construction of the drones in a military capacity was around 1916, during World War I, though the concept had been around for a long time. In 1849, the Italian military had used tactical weather balloons for bomb deployment. These particular war balloons would reach a certain height and then drop bombs. However, these “drones” were easier to deal with since they were balloons. The airplanes used during World War I were a better way to deploy aerial weapons. Trench warfare became outdated in the conflicts that came after World War I because now, an attacker can be far from those being attacked.

World War I military drones remained at the basic level of testing rather than used in combat. They were designed to work in the way torpedoes are used today in submarines, but they were not ready in time for use in that war. Reginald Denny is credited with creating a more modern and much more accurate drone in 1935 with the prototype RP-1, which he showed to the U.S. Army. Throughout the 1930s, Denny and his group, the Radioplane Company, continued to make new models of the RP series. The RP series worked via radio control; however, the first drone that consistently worked via radio while the drone was out of visible range was created by Edward M. Sorensen.

The U.S. Army experimented with drone warfare concepts during the 1930s as well. Throughout the 1940s and 1950s, there were many attempts to increase the potential of drones. Examples include the “Firebees” from 1951 that could fly for two hours straight at heights around 60,000 feet and World War II’s British Operation Aphrodite. In it, older planes and bombers were used to launch a variation of kamikaze attack on German strongholds. The British pilots would jump out of the planes within a certain range to the target, and radio control would take over to attempt a dive-bomb. During the Vietnam War, drones called the “Lightning Bugs” were used. The reason behind the name was the quick flash of

light when their payload hit the target. They flew around 3,500 missions. Unfortunately, with the state of the economy then, it was far too expensive to use costly drones in that conflict. Although this is an example of drones not being economically feasible, in modern times, construction upgrades have reversed that issue.

Drones have now seen an immense increase in usage in desert-related conflicts. Waging war in the Middle East is already difficult, partly because there are few huge strongholds or cities to target easily, especially as many are hidden by the desert itself, or the enemy is cell based and moves underground in tunnels. The interest in more precise drones increased in reaction to the terrorist attacks of September 11, 2001, in the United States. Current drones are much smaller than those of yesteryear. Currently, the most well-known drone used by the United States is the MQ 1 Predator missile. It has over 200 that can be flown across the planet for precision strikes. In 2015, the number of kills achieved by Predator missiles was well over 3,900. The Predator uses satellite imaging and computers for targeting rather than the radio concept of older models. However, it still needs to initiate contact with a ground facility to use its talents properly.

The importance of military-based drones has been proven through the tactical information that they can provide and the strikes they are capable of from a very safe distance. Developing even precision is of the utmost importance to protect innocent civilians near strike zones so prevent them from becoming casualties of war. Restrictions can be built into drones, and constant updating of the knowledge of drones in use by other world powers is paramount for keeping countries safe from strikes.

Drones can be very useful but are much like the new nuclear weapons in their potential as tools to make other countries yield. The main function of drones is to attack at a distance while keeping one’s own military as safe as possible. Drones are now being considered for domestic use in the United States to survey situations and help the police react as needed.

Elijah Turner

See also *Vol. 2, Sec. 1: Military Technology (Post-Civil War through World War I); Vol. 2, Sec. 3: Military Technology (World War II)*

Further Reading

- Goodman, Robin Truth. 2015. “A *Theory of the Drone* by Grégoire Chamayou” (Review). *symploke* 23, no. 1: 518–20.
- Shaw, Ian G. R. 2014. “The Rise of the Predator Empire: Tracing the History of U.S. Drones.” *Understanding Empire: Technology, Power, Politics*. <https://understandingempire.wordpress.com/2-0-a-brief-history-of-u-s-drones/>, accessed August 31, 2018.

Electric Car

Electric cars have a long history in the United States, as they were first used in the mid-to-late-1800s. In modern times, the need for alternatives to hydrocarbon-based fuels has increased immensely, as have the abilities of electric vehicles. Hydrocarbon fuels, also known as fossil fuels, represent a finite source on the planet, while electricity can be continually generated. Steam was another option used for cars in early days, but it proved less practical than electricity or fossil fuels.

One of the first electric vehicles was built in 1859 in France, crafted by Gaston Plante. It used a lead-acid battery to store electrical energy. The design was refined by Camille Alphonse Faure around 1881, leading to better capacity in the battery and therefore longer usage of the car. In 1890 in the United States, William Morrison, a chemist, designed the first electric car, a six-passenger vehicle capable of a top speed of 14 miles per hour.

Shortly afterward, electric cars enjoyed a relative period of success, beating many speed records, and the public seemed interested. By the end of the 1800s, electric taxis became the norm in London, which helped the economy and British tourism goals. While gasoline-powered cars debuted around the same time, they had detractors. Drivers complained about the strength required to change gears and of the inconvenience of starting the cars with a hand crank. Gasoline-powered engines were loud, and the exhaust caused coughing and dirty clothing.

Thomas Edison believed in the superiority of electric technology and developed a more powerful electric vehicle battery. He partnered with Henry Ford to design a low-cost electric car, but Ford continued to sell gasoline-powered cars and made more of them on his

moving assembly line and therefore, they were more affordable. In 1912, his Model T gasoline-powered car cost \$650, while an electric roadster sold for \$1,750.

Customers began to see that electric cars had their drawbacks, as they were slower and could not go far outside city limits. Electric cars declined in popularity in the 1920s, as they simply could not measure up to petroleum-powered cars, which were boosted by the newly discovered oil fields across the country. These oil reserves stole attention from the electric car, as it was easier to use gasoline than charge a battery. However, electricity was still a component in gasoline-powered cars, as they used an electric starter crafted by Charles Kettering before the 1920s. Electric cars soon fell out of the limelight.

The oil shortage in the 1960s and 1970s encouraged the U.S. government to pass the Electric and Hybrid Vehicle Research, Development, and Demonstration Act of 1976, pushing for more research into electric and hybrid vehicles. In 1971, there was an opportunity for the electric vehicle to show its worth as a manned electrical buggy became famous as the first vehicle on the surface of the moon. A fossil fuel buggy would obviously have been an issue as soon as it ran out of fuel. But this buggy generated its own energy.

However, none of these attempts garnered enough respect or buzz in the world for electric cars to challenge gasoline-powered cars. Despite the gas crisis, after the 1970s, there was a deep drop in interest in them. It wasn't until the 1990s that interest in using electric energy returned, especially with the government passing new clean air acts to help usher in an ecologically safer environment for the public to contribute to through their vehicle choices.

One of the most famous models of electric cars is one that is not fully electric but a hybrid. The Toyota Prius, introduced in Japan in 1997, was a big success on the nationwide market. Then in the new millennium, Tesla Motors, a California motor company named for Nikola Tesla, began working on all-electric cars in 2004. It brought out its first example, the Tesla Roadster, in 2008, but it stopped selling them in 2011, as a crucial part needed to construct it had run out.

The potential of electrically powered vehicles has grown as people recognize that the fossil fuels we have come to rely on have a finite life. Electrically

powered vehicles are also much cleaner in construction today and leave a cleaner ecological footprint on the roads they travel.

However, until these vehicles are cheaper and more accessible, the world will continue to rely on gasoline-fueled models.

Elijah Turner

See also *Vol. 2, Sec. 1*: Edison, Thomas; Tesla, Nikola; *Vol. 2, Sec. 2*: Ford, Henry; *Vol. 3, Sec. 2*: Self-Driving Cars

Further Reading

- “The History of the Electric Car.” 2014. Energy.gov. September 15. <https://www.energy.gov/articles/history-electric-car>, accessed September 25, 2018.
- Westbrook, M. 2001. *The Electric Car: Development and Future of Battery, Hybrid and Fuel-cell Cars*. London: Institution of Electrical Engineers.
- Zhang, Q., and Y. Yang. 2012. “A Smart Motor Speed Controller of Electrical Car.” *Advanced Materials Research* 580: 141–45.

Primary Document: Article from the energy.gov Web Site on Electric Cars (2014)

Once we run out of fossil fuels, humans will need to find a new power source for vehicles in the public sector, so we have recently returned to electricity as a possible source. This article from the energy.gov website illustrates the development of electronic cars in the United States. The concept has been around for over a hundred years.

By Rebecca Matulka

Introduced more than 100 years ago, electric cars are seeing a rise in popularity today for many of the same reasons they were first popular.

Whether it's a hybrid, plug-in hybrid or all-electric, the demand for electric drive vehicles will continue to climb as prices drop and consumers look for ways to save money at the pump. Currently more than 3 percent of new vehicle sales, electric vehicles sales could to grow to nearly 7 percent—or 6.6 million per year—worldwide by 2020, according to a report by Navigant Research.

With this growing interest in electric vehicles, we are taking a look at where this technology has been and where it's going. Travel back in time with us as we explore the history of the electric car.

THE BIRTH OF THE ELECTRIC VEHICLE

It's hard to pinpoint the invention of the electric car to one inventor or country. Instead it was a series of breakthroughs—from the battery to the electric motor—in the 1800s that led to the first electric vehicle on the road.

In the early part of the century, innovators in Hungary, the Netherlands and the United States—including

a blacksmith from Vermont—began toying with the concept of a battery-powered vehicle and created some of the first small-scale electric cars. And while Robert Anderson, a British inventor, developed the first crude electric carriage around this same time, it wasn't until the second half of the 19th century that French and English inventors built some of the first practical electric cars.

Here in the U.S., the first successful electric car made its debut around 1890 thanks to William Morrison, a chemist who lived in Des Moines, Iowa. His six-passenger vehicle capable of a top speed of 14 miles per hour was little more than an electrified wagon, but it helped spark interest in electric vehicles.

Over the next few years, electric vehicles from different automakers began popping up across the U.S. New York City even had a fleet of more than 60 electric taxis. By 1900, electric cars were at their heyday, accounting for around a third of all vehicles on the road. During the next 10 years, they continued to show strong sales.

THE EARLY RISE AND FALL OF THE ELECTRIC CAR

To understand the popularity of electric vehicles circa 1900, it is also important to understand the development of the personal vehicle and the other options available. At the turn of the 20th century, the horse was still the primary mode of transportation. But as Americans became more prosperous, they turned to the newly invented motor vehicle—available in steam, gasoline or electric versions—to get around.

Steam was a tried and true energy source, having proved reliable for powering factories and trains.

Some of the first self-propelled vehicles in the late 1700s relied on steam; yet it took until the 1870s for the technology to take hold in cars. Part of this is because steam wasn't very practical for personal vehicles. Steam vehicles required long startup times—sometimes up to 45 minutes in the cold—and would need to be refilled with water, limiting their range.

As electric vehicles came onto the market, so did a new type of vehicle—the gasoline-powered car—thanks to improvements to the internal combustion engine in the 1800s. While gasoline cars had promise, they weren't without their faults. They required a lot of manual effort to drive—changing gears was no easy task and they needed to be started with a hand crank, making them difficult for some to operate. They were also noisy, and their exhaust was unpleasant.

Electric cars didn't have any of the issues associated with steam or gasoline. They were quiet, easy to drive and didn't emit a smelly pollutant like the other cars of the time. Electric cars quickly became popular with urban residents—especially women. They were perfect for short trips around the city, and poor road conditions outside cities meant few cars of any type could venture farther. As more people gained access to electricity in the 1910s, it became easier to charge electric cars, adding to their popularity with all walks of life (including some of the “best known and prominent makers of gasoline cars” as a 1911 New York Times article pointed out).

Many innovators at the time took note of the electric vehicle's high demand, exploring ways to improve the technology. For example, Ferdinand Porsche, founder of the sports car company by the same name, developed an electric car called the P1 in 1898. Around the same time, he created the world's first hybrid electric car—a vehicle that is powered by electricity and a gas engine. Thomas Edison, one of the world's most prolific inventors, thought electric vehicles were the superior technology and worked to build a better electric vehicle battery. Even Henry Ford, who was friends with Edison, partnered with Edison to explore options for a low-cost electric car in 1914, according to *Wired*.

Yet, it was Henry Ford's mass-produced Model T that dealt a blow to the electric car. Introduced in 1908, the Model T made gasoline-powered cars widely available and affordable. By 1912, the gasoline car cost only \$650, while an electric roadster sold for \$1,750. That same year, Charles Kettering

introduced the electric starter, eliminating the need for the hand crank and giving rise to more gasoline-powered vehicle sales.

Other developments also contributed to the decline of the electric vehicle. By the 1920s, the U.S. had a better system of roads connecting cities, and Americans wanted to get out and explore. With the discovery of Texas crude oil, gas became cheap and readily available for rural Americans, and filling stations began popping up across the country. In comparison, very few Americans outside of cities had electricity at that time. In the end, electric vehicles all but disappeared by 1935.

GAS SHORTAGES SPARK INTEREST IN ELECTRIC VEHICLES

Over the next 30 years or so, electric vehicles entered a sort of dark ages with little advancement in the technology. Cheap, abundant gasoline and continued improvement in the internal combustion engine hampered demand for alternative fuel vehicles.

Fast forward to the late 1960s and early 1970s. Soaring oil prices and gasoline shortages—peaking with the 1973 Arab Oil Embargo—created a growing interest in lowering the U.S.'s dependence on foreign oil and finding homegrown sources of fuel. Congress took note and passed the Electric and Hybrid Vehicle Research, Development, and Demonstration Act of 1976, authorizing the Energy Department to support research and development in electric and hybrid vehicles.

Around this same time, many big and small automakers began exploring options for alternative fuel vehicles, including electric cars. For example, General Motors developed a prototype for an urban electric car that it displayed at the Environmental Protection Agency's First Symposium on Low Pollution Power Systems Development in 1973, and the American Motor Company produced electric delivery jeeps that the United States Postal Service used in a 1975 test program. Even NASA helped raise the profile of the electric vehicle when its electric Lunar rover became the first manned vehicle to drive on the moon in 1971.

Yet, the vehicles developed and produced in the 1970s still suffered from drawbacks compared to gasoline-powered cars. Electric vehicles during this time had limited performance—usually topping at speeds of 45 miles per hour—and their typical range was limited to 40 miles before needing to be recharged.

ENVIRONMENTAL CONCERN DRIVES ELECTRIC VEHICLES FORWARD

Fast forward again—this time to the 1990s. In the 20 years since the long gas lines of the 1970s, interest in electric vehicles had mostly died down. But new federal and state regulations begin to change things. The passage of the 1990 Clean Air Act Amendment and the 1992 Energy Policy Act—plus new transportation emissions regulations issued by the California Air Resources Board—helped create a renewed interest in electric vehicles in the U.S.

During this time, automakers began modifying some of their popular vehicle models into electric vehicles. This meant that electric vehicles now achieved speeds and performance much closer to gasoline-powered vehicles, and many of them had a range of 60 miles.

One of the most well-known electric cars during this time was GM's EV1, a car that was heavily featured in the 2006 documentary *Who Killed the Electric Car?* Instead of modifying an existing vehicle, GM designed and developed the EV1 from the ground up. With a range of 80 miles and the ability to accelerate from 0 to 50 miles per hour in just seven seconds, the EV1 quickly gained a cult following. But because of high production costs, the EV1 was never commercially viable, and GM discontinued it in 2001.

With a booming economy, a growing middle class and low gas prices in the late 1990s, many consumers didn't worry about fuel-efficient vehicles. Even though there wasn't much public attention to electric vehicles at this time, behind the scenes, scientists and engineers—supported by the Energy Department—were working to improve electric vehicle technology, including batteries.

A NEW BEGINNING FOR ELECTRIC CARS

While all the starts and stops of the electric vehicle industry in the second half of the 20th century helped show the world the promise of the technology, the true revival of the electric vehicle didn't happen until around the start of the 21st century. Depending on whom you ask, it was one of two events that sparked the interest we see today in electric vehicles.

The first turning point many have suggested was the introduction of the Toyota Prius. Released in

Japan in 1997, the Prius became the world's first mass-produced hybrid electric vehicle. In 2000, the Prius was released worldwide, and it became an instant success with celebrities, helping to raise the profile of the car. To make the Prius a reality, Toyota used a nickel metal hydride battery—a technology that was supported by the Energy Department's research. Since then, rising gasoline prices and growing concern about carbon pollution have helped make the Prius the bestselling hybrid worldwide during the past decade.

(Historical footnote: Before the Prius could be introduced in the U.S., Honda released the Insight hybrid in 1999, making it the first hybrid sold in the U.S. since the early 1900s.)

The other event that helped reshape electric vehicles was the announcement in 2006 that a small Silicon Valley startup, Tesla Motors, would start producing a luxury electric sports car that could go more than 200 miles on a single charge. In 2010, Tesla received a \$465 million loan from the Department of Energy's Loan Programs Office—a loan that Tesla repaid a full nine years early—to establish a manufacturing facility in California. In the short time since then, Tesla has won wide acclaim for its cars and has become the largest auto industry employer in California.

Tesla's announcement and subsequent success spurred many big automakers to accelerate work on their own electric vehicles. In late 2010, the Chevy Volt and the Nissan LEAF were released in the U.S. market. The first commercially available plug-in hybrid, the Volt has a gasoline engine that supplements its electric drive once the battery is depleted, allowing consumers to drive on electric for most trips and gasoline to extend the vehicle's range. In comparison, the LEAF is an all-electric vehicle (often called a battery-electric vehicle, an electric vehicle or just an EV for short), meaning it is only powered by an electric motor.

Over the next few years, other automakers began rolling out electric vehicles in the U.S.; yet, consumers were still faced with one of the early problems of the electric vehicle—where to charge their vehicles on the go. Through the Recovery Act, the Energy Department invested more than \$115 million to help build a nation-wide charging infrastructure,

installing more than 18,000 residential, commercial and public chargers across the country. Automakers and other private businesses also installed their own chargers at key locations in the U.S., bringing today's total of public electric vehicle chargers to more than 8,000 different locations with more than 20,000 charging outlets.

At the same time, new battery technology—supported by the Energy Department's Vehicle Technologies Office—began hitting the market, helping to improve a plug-in electric vehicle's range. In addition to the battery technology in nearly all of the first generation hybrids, the Department's research also helped develop the lithium-ion battery technology used in the Volt. More recently, the Department's investment in battery research and development has helped cut electric vehicle battery costs by 50 percent in the last four years, while simultaneously improving the vehicle batteries' performance (meaning their power, energy and durability). This in turn has helped lower the costs of electric vehicles, making them more affordable for consumers.

Consumers now have more choices than ever when it comes to buying an electric vehicle. Today, there are 23 plug-in electric and 36 hybrid models available in a variety of sizes—from the two-passenger Smart ED to the midsize Ford C-Max Energi to the BMW i3 luxury SUV. As gasoline prices continue to rise and the prices on electric vehicles continue to drop, electric vehicles are gaining in popularity—with more than 234,000 plug-in electric vehicles and 3.3 million hybrids on the road in the U.S. today.

THE FUTURE OF ELECTRIC CARS

It's hard to tell where the future will take electric vehicles, but it's clear they hold a lot of potential for creating a more sustainable future. If we transitioned all the light-duty vehicles in the U.S. to hybrids or plug-in electric vehicles using our current technology mix, we could reduce our dependence on foreign oil by 30-60 percent, while lowering the carbon pollution from the transportation sector by as much as 20 percent.

To help reach these emissions savings, in 2012 President Obama launched the EV Everywhere Grand Challenge—an Energy Department initiative that brings together America's best and brightest

scientists, engineers and businesses to make plug-in electric vehicles more as affordable as today's gasoline-powered vehicles by 2022. On the battery front, the Department's Joint Center for Energy Storage Research at Argonne National Laboratory is working to overcome the biggest scientific and technical barriers that prevent large-scale improvements of batteries.

And the Department's Advanced Research Projects Agency-Energy (ARPA-E) is advancing game-changing technologies that could alter how we think of electric vehicles. From investing in new types of batteries that could go further on a single charge to cost-effective alternatives to materials critical to electric motors, ARPA-E's projects could transform electric vehicles.

In the end, only time will tell what road electric vehicles will take in the future.

WHAT'S THE DIFFERENCE?

A hybrid electric vehicle (or HEV for short) is a vehicle without the capacity to plug in but has an electric drive system and battery. Its driving energy comes only from liquid fuel. Learn about the history of the hybrid—from the world's first one to the world's bestselling one.

A plug-in hybrid electric vehicle (also called a PHEV) is a vehicle with plug-in capability, and it can use energy for driving from either its battery or liquid fuel. Read about the first commercially available plug-in hybrid.

An all-electric vehicle (often called a battery-electric vehicle, an electric vehicle, or an EV or AEV for short) is a vehicle that gets its energy for driving entirely from its battery and it must be plugged in to be recharged. Explore the evolution of the electric vehicle, covering everything from its early popularity to the middle ages to its revival today.

A plug-in electric vehicle (or PEV) is any vehicle that can be plugged in (either a plug-in hybrid or an all-electric vehicle). Learn how plug-in electric vehicles could help us create a more sustainable future.

Source: Department of Energy: <http://energy.gov/articles/history-electric-car>, accessed August 31, 2018.

Enders, John Franklin (1897–1985)

John Franklin Enders was a Nobel Prize virologist whose pioneering discoveries in the field of virology granted him the title of “the Father of Modern Vaccines.” Together with his colleagues Thomas Weller and Frederick Robbins, he discovered new tissue culture techniques to grow viruses that later led to the development of poliomyelitis and measles vaccines. His groundbreaking discoveries have saved over 100 million lives.

Enders was born in West Hartford, Connecticut, on February 10, 1897. Son of a banker in Hartford, he showed no interest in science during his youth. After attending Yale University for just two years, Enders joined the U.S. Air Force in 1917, becoming a pilot with the rank of ensign. When the First World War was over, he returned to Yale, where he was awarded his AB in English in 1919. He tried to follow in his father’s footsteps, working in real estate for two years, but he quickly found this career to be rather dull. In the next four years, he enrolled in graduate school at Harvard to study English literature as well as Germanic and Celtic languages, hoping to become an English teacher. However, he was not happy about this choice either, and in 1927, he left his studies to enter as a candidate for the PhD degree in bacteriology and immunology after being introduced to his new mentor, Dr. Hans Zinsser. After he earned his PhD in 1930, Enders joined the bacteriology faculty at Harvard Medical School, where he remained until the end of his career.

In 1941, Enders and his colleagues Cohen, Stokes, Kane, and others, started a study of the virus of mumps that demonstrated the immunizing effects of inactivated viruses. In 1946, he established a laboratory at Children’s Hospital in Boston, where he led several studies on the polio virus. In 1949, together with Thomas Huckle Weller and Frederick Chapman Robbins, Enders came up with a breakthrough discovery that revolutionized the fight against the ongoing poliomyelitis epidemic that ravaged the United States. Before this research, scientists who wanted to grow the polio virus were forced to inoculate it in live monkeys and later retrieve minuscule quantities from their corpses during autopsies. The newly discovered Enders technique allowed researchers to culture the virus in test tubes, paving the way for the mass production of the Jonas Salk vaccine and Albert Sabin’s killed-virus and live-virus vaccines. This

technique quickly became an invaluable tool for all virologists across the world by reducing the cost and time required to study many other viruses as well. In 1954, Enders, Weller, and Robbins received the Nobel Prize in Physiology or Medicine for their work on culturing the polio virus in various types of tissue.

After being appointed professor at Harvard University and chief of the Research Division of Infectious Diseases at Children’s Hospital, in 1953, Enders formed a new team with Thomas Peebles to start researching the measles virus. Although measles did not kill patients who contracted it in Western countries outright, it was an extremely contagious disease that affected 9 out of 10 children. More than 6 million children who caught it died every year in less developed regions of the world, nearly twice as many as those who died from polio. After Enders’s team had isolated the virus, they started developing an attenuated live-virus measles vaccine. In 1960, he handed the vaccine off to Dr. Maurice Hilleman, who was the head of the research department at the pharmaceutical company Merck, Sharp, and Dohme. Hilleman perfected and distributed it in 1963.

Enders was a member of the American Academy of Arts and Sciences, the National Academy of Sciences, and the American Philosophical Society. During his career, he received several prizes, including the Albert Lasker Basic Medical Research Award (1954), the Presidential Medal of Freedom (1963), and the Robert Koch Prize (1963). He was also awarded honorary doctoral degrees from 13 universities.

Enders officially retired in 1967 at the age of 70. However, he kept teaching and researching up until 1976, as he continued the studies on virus-host relationships and viral oncogenesis he had started in 1959. He died on September 8, 1985, in his home in Waterford, Connecticut, at the age of 88.

Claudio Butticiè

See also Antibiotic

Further Reading

- Rosen, F. S. 2004. “Isolation of Poliovirus—John Enders and the Nobel Prize.” *New England Journal of Medicine* 351, no. 15: 1481–83.
- Weller, T. H., and F. C. Robbins. 1991. *John Franklin Enders. Biographical Memoirs*. Washington, D.C.: National Academies Press.

Engelbart, Douglas (1925–2013)

The grandson of pioneers in the West, Douglas Engelbart was known as an engineer and inventor. Engelbart, known as “Doug” to many, also served in the military for two years, but he is mainly known as the creator of the computer mouse. Also, he had a vision all his life for “augmenting the human intellect” through working with interactive computers and helping intellectual workers to become more capable.

Engelbart was born on January 30, 1925, in Portland, Oregon. He was the son of Carl and Gladys Engelbart. He had two other siblings: an older sister named Dorianne Engelbart Vadnais and a younger brother named David Engelbart. He attended Franklin High School and then Oregon State University. There, he studied electrical engineering. In 1944, he enlisted in the navy during World War II and served two years as an electronic and radar technician stationed in the Philippines.

In 1948, he earned a bachelor’s degree and was given a position at California’s Ames Research Center. This was a government laboratory overseen by the National Advisory Committee for Aeronautics. He spent a number of years there before earning his PhD in electrical engineering at the University of California, Berkeley. In 1957, he took a research position at Stanford Research Institute.

In 1961, Engelbart first came up with the idea of the computer mouse as a way to make interactive computing easier. He built the first prototype in 1964, carving it from wood. It had wheels on the bottom so the computer could track the rotation of the mouse and move the cursor displayed on the computer screen. Finally, there was a button on the right corner, used for clicking items on the screen.

Over the years, the dimensions and materials of the computer mouse gradually changed, but its purpose has remained the same. Douglas Engelbart developed many computer-related inventions, including interactive computing and the keyset. After many years of success, Douglas Engelbart died July 2, 2013 in Atherton, California.

Marissa A. Guerrero

See also Vol. 3, Sec. 2: Apple II; Personal Computer (PC)

Further Reading

- Bardini, T. 2000. *Bootstrapping: Douglas Engelbart, Coevolution, and the Origins of Personal Computing*. Stanford University Press.
- Barnes, S. B. 1997. “Douglas Carl Engelbart: developing the underlying concepts for contemporary computing.” *IEEE Annals of the History of Computing* 19, no. 3: 16–26.
- Barnet, B. 2006. “Engelbart’s Theory of Technical Evolution.” *Continuum: Journal of Media & Cultural Studies* 20, no. 4: 509–21.
- Doug Engelbart Institute. n.d. “Father of the Mouse.” <http://dougengelbart.org/firsts/mouse.html>, accessed August 31, 2018.
- “Douglas C. Engelbart Biography.” Biography. <http://www.biography.com/people/douglas-c-engelbart-9287574>, accessed August 31, 2018.

ENIAC and the “ENIAC Girls”

ENIAC, or “Electrical Numerical Integrator and Computer,” was the first electronic general-purpose computer. It was used to calculate artillery firing tables for the U.S. Army’s Ballistic Research Laboratory and to study the feasibility of thermonuclear weapons. It was primarily operated by a group of women known as the “ENIAC Girls.”

Financed by the U.S. Army, Ordnance Corps, Research and Development Command at a cost of \$487,000, ENIAC was the first electronic general-purpose computer in the world. The computer was designed by John Mauchly and J. Presper Eckert with the assistance of Robert F. Shaw (function tables), Jeffrey Chuan Chu (divider/square-rooter), Thomas Kite Sharpless (master programmer), Frank Mural (master programmer), Arthur Burks (multiplier), Harry Huskey (reader/printer), and Jack Davis (accumulators). ENIAC was completed in secret in 1943 at the University of Pennsylvania’s Moore School of Electrical Engineering, under the code name “Project PX,” and formally dedicated on February 15, 1946.

ENIAC was a modulator computer, composed of individual panels to perform different functions, at a speed one thousand times faster than previous electro-mechanical machines. Twenty of its panels were accumulators, which could add, subtract, and hold a 10-digit

decimal number in memory. Punch cards from an IBM card reader were used as external memory. ENIAC could also be programmed to perform complex sequences of operations, including loops, branches, and subroutines. The task of mapping a problem onto the machine to run the operations was complex and usually took weeks of figuring out the program on paper, manipulating switches and cables, verification, and debugging.

To accomplish this task, the army hired a group of female programmers, known as the “ENIAC Girls,” drafted from the Moore School of Electrical Engineering at the University of Pennsylvania. The original group included Kay McNulty, Betty Jennings, Betty Snyder, Marlyn Wescoff, Fran Bilas, and Ruth Lichterman. They were tasked with determining how to input programs into the computer and develop an understanding of ENIAC’s inner workings by crawling inside the machine to fix problems and make observations. None of the ENIAC Girls received public recognition for their work, which was classified as a clerical task. Some have since been recognized for their contributions to computing, including their induction into the Women in Technology International Hall of Fame in 1997.

Following the original group of six, over one hundred scientists were recruited to continue work on ENIAC, including several women. Their work played a key role in several computing developments, including the first computations for the hydrogen bomb and the popularization of the Monte Carlo method, which calculated the distance that neutrons would likely travel through various materials. ENIAC was shut down on November 9, 1946, for a refurbishment and a memory upgrade. It was transferred to the Aberdeen Proving Ground in Maryland in 1947, where it remained in continuous operation until 11:45 p.m. on October 2, 1955. Unlike other computers of its time, ENIAC was widely discussed in the press. Its one-of-a-kind design formed the basis for later computers, and today, several parts of ENIAC are on display at museums in the United States, England, and Germany.

Tiffany Rhoades

See also Mercury 13; *Vol. 2, Sec. 1*: Harvard Computers; *Vol. 2, Sec. 3*: Calutron Girls; Curtiss-Wright Aeronautical Engineering Cadettes; *Vol. 3, Sec. 3*: Jemison, Mae

Further Reading

McCartney, Scott. 1999. *ENIAC: The Triumphs and Tragedies of the World’s First Computer*. New York: Walker.

Fortran

Fortran, or FORTRAN, derives its name from “formula translation,” the computer language that introduced the concept of compilers. Fortran allowed software to be produced for all types of hardware and was a pivotal programming language in the electronic revolution of the late 20th century.

In the mid-20th century, software was heavily defined by the hardware it was applied to; programmers who coded for a specific hardware had to manually manage the allocation of memory and such in their code. Thus, code on one machine would not necessarily be able to function on a machine that contained different memory allocations, system details, and so on. Because of this, producing code was both inefficient and tedious for programmers.

From 1954 to 1957, a development team at International Business Machines (IBM) led by John Backus produced a software language that worked around this issue. IBM shipped the software out with the IBM 704 computer.

Fortran was the first programming language that was made to be independent from the hardware system. It featured a compiler that allowed high-level code, which resembled words and sentence-like structures. These structures were compiled into machine language composed of 0s and 1s. Through this compiler, programmers could worry less about hardware-dependent issues and focus their efforts on solving the mathematical and/or logical issues with the problem at hand. Because of this, one of the major advantages of the language was its ability to speed up the process of software development; even though the software performance was reduced by about a fifth, the compiler alone made coding five times more efficient.

Additionally, Fortran solved a number of other issues persistent in previous programming languages. Fortran became one of the first languages that could identify parenthetical operations in mathematical

statements and thus could properly translate with the correct order of operations. This made number crunching significantly easier, because the functions could now be expressed more algebraically. As such, the programming language was heavily favored in applications that required high-performance computation, such as engineering models and simulations. Furthermore, the language introduced concepts of comments in the code, a convention that improved code quality and became common coding practice.

Fortran revolutionized the software industry by improving the efficiency of both the language capabilities and the programmer. It inspired the birth of many other common programming languages, such as C, C++, and more, and is still used in computation for scientific models in fields such as fluid dynamics, physics, chemistry, and meteorology due to its ability to rapidly compute numerical calculations.

Peg A. Lamphier

See also Intel Corporation; *Vol. 3, Sec. 2*: Apple; Computer/Information Technology

Further Reading

Maney, Kevin. 2003. *The Maverick and His Machine: Thomas Watson, Sr. and the Making of IBM*. Wiley.

Wexelblat, Richard L. 2014. *History of Programming Languages (ACM Monograph Series)*. Academic Press.

Fuller, Richard Buckminster (1895–1983)

A geodesic dome is a sphere made up of multitudes of triangles put together, almost forming small pyramids, in the shape of a sphere. This complex building structure was created by American inventor Richard Buckminster Fuller, also known as “Bucky.” The most famous of Fuller’s designs was the Biosphere located in Montreal on Saint Helen’s Island. The United States employed Fuller to design the pavilion for the 1967 World’s Fair Exposition in Montreal. The Biosphere stands 62 meters high, with a diameter of 67 meters. It is taller than a seven-story building. In 1976, the acrylic surrounding the dome caught fire during routine welding maintenance. In 1995, the Biosphere was reopened to the

public as a museum dedicated to environmental action. Closed once again in 1998 after a damaging ice storm, the Biosphere and its museum were reopened five months later.

Fuller was born on July 12, 1895, in Milton, Massachusetts. When he was young, Fuller and his family would take trips to Bear Island in Maine, and that’s how he learned how to build and repair boats. He entered Harvard College in 1913 but was soon expelled due to socializing too much and neglecting his midterms. After his expulsion, Fuller worked for a mill in Canada, where he became interested in the inner works of the mill equipment and learned how to improve it. Fuller later reapplied to Harvard and was accepted, but he was soon expelled again.

Fuller served in the U.S. Navy from 1917 to 1919. During this time, he invented a winch that could fish downed planes out of the water. Impressed by his invention, the navy nominated him for officer training at the Naval Academy, where he studied how to look at problems thoroughly. In 1926, Fuller helped his father-in-law patent his new method of strengthening concrete, which became the first of his many patents. A year later, Fuller invented a housing structure that could be quickly and easily delivered by air: the Dymaxion House. It was originally called the “4D House,” but the name was later changed by a store that advertised them. Along with the Dymaxion homes, Fuller also created Dymaxion cars, which had three wheels and great turning maneuverability. He also invented the Dymaxion Bathroom and Dymaxion Development Units, or DDUs for short, which were used during World War II to shield radar crews from harsh weather.

In 1944, the United States suffered from low housing availability. Needing housing that could be made quickly and easily, the government looked to Fuller to help end this crisis. Multitudes of people began to send in checks for Dymaxion homes, but unfortunately, Fuller could not get their production into full throttle. He felt that his design could be improved in some way, so he set out to perfect it.

In 1947, Fuller designed the building structure for which he would be most known, the geodesic dome. His design was easy to assemble, it was low cost, and it was lighter than other structures. The spherical shape of the dome allowed for more volume internally

while using the least amount of surface area, which meant less material required for manufacture. The spherical shape also allowed for easier air circulation and therefore easier heating and cooling. Fuller patented the geodesic dome in 1954. The military turned out to be Fuller's biggest client, using his dome to mask radar stations. Fuller died on July 1, 1983, in Los Angeles, but his geodesic domes are still being used all around the world.

Rosanne Welch

See also Vol. 2, Sec. 3: Military Technology (World War II)

Further Reading

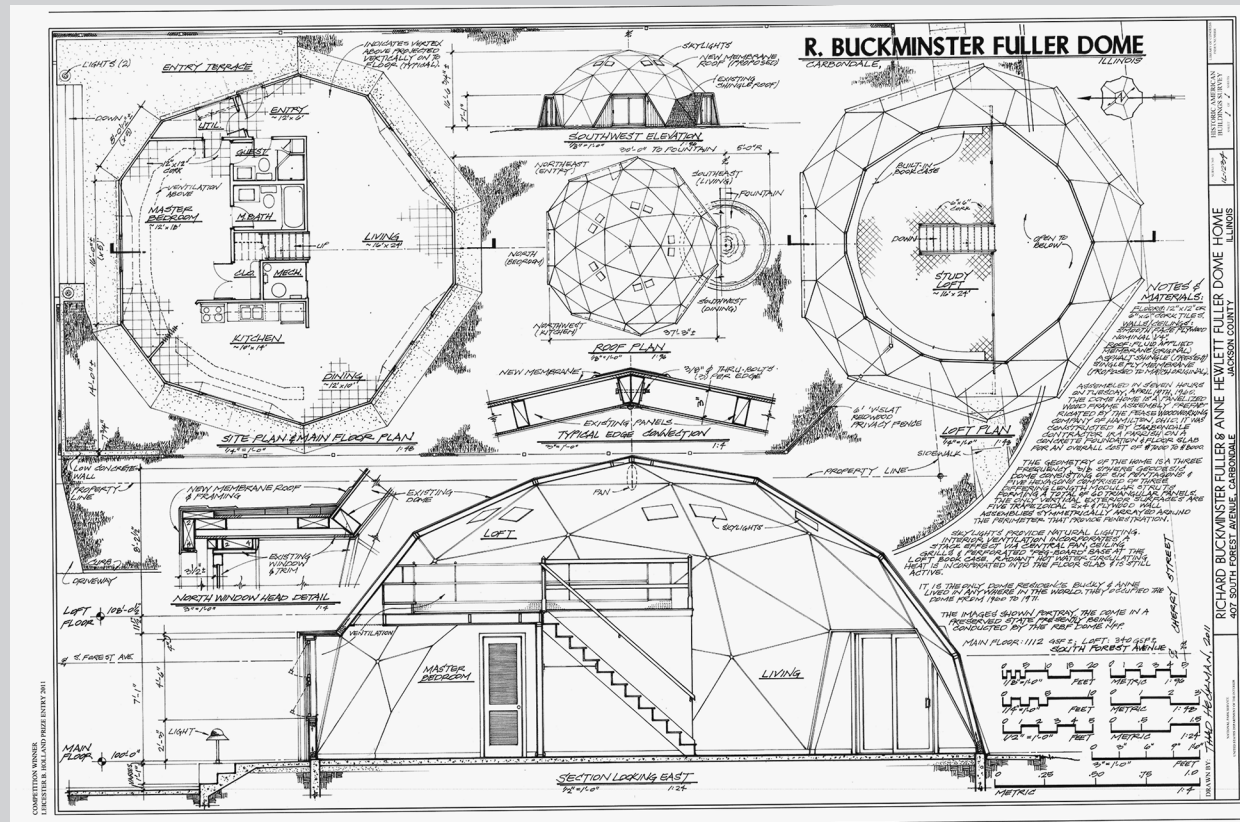
- "About Fuller: Geodesic Domes." *Buckminster Fuller Institute*. <https://www.bfi.org/about-fuller/big-ideas/geodesic-domes>, accessed August 31, 2018.
- Glacey, J. 2014. *The Story of Buckminster Fuller's Radical Geodesic Dome*. October 21. <http://www.bbc.com/culture/story/20140613-spaceship-earth-a-game-of-domes>, accessed August 31, 2018.
- Langdon, D. 2014. *AD Classics: Montreal Biosphere/ Buckminster Fuller*. November 25. <https://www.archdaily.com/572135/ad-classics-montreal-biosphere-buckminster-fuller>, accessed September 25, 2018.

Primary Document: Drawing of R. Buckminster Fuller's Geodesic Dome (c. 1933)

Richard Buckminster Fuller had a vision of homes that could be fabricated in a factory and easily flown in by helicopter to any location and lived in comfortably. The structure of these houses is now called the geodesic dome, but Fuller first named his odd idea the Dymaxion House. The idea of living in a dome home was not a popular one, but Fuller gained a

patent for it, and several were made for the U.S. Marine Corps. The best known of Fuller's designs is the U.S. Pavilion at the 1967 Expo in Montreal. Fuller also lived in a geodesic house with his wife, Anne, in which he designed many other domes.

Source: Library of Congress.



Geodesic Dome. See Fuller, Richard Buckminster

Global Positioning System (GPS)

Global Positioning System (GPS) is a satellite utility owned and maintained by the U.S. Department of Defense. GPS provides military and civilians with timing, positioning, and navigation services. Roger L. Easton of the Naval Research Laboratory, Ivan A. Getting of the Aerospace Corporation, and Bradford Parkinson of the Applied Physics Laboratory are credited with its invention. The U.S. Air Force launched the first GPS satellite, the Navigation Satellite with Timing and Ranging (NAVSTAR), on February 22, 1978.

The GPS system consists of three segments: the space segment, the control segment, and the user segment. The space segment is made up of a constellation of at least 24 NAVSTARs precisely orbiting the earth twice in the span of 24 hours. The satellites are set in a way that allows at least four of them to be in direct line of sight from anywhere on earth. Each satellite has an extremely accurate atomic clock powered by quantum physics. The satellites each transmit a unique signal (with the exact time it is sent) called Pseudo Random Code (PRC) so that they don't interfere with each other. Each NAVSTAR weighs 2,200 pounds and travels 8,640 miles per hour.

The GPS receiver (the user segment) receives these signals. The amount of time it takes the receiver to get the signals determines the distance between the satellites and the receiving device (distance = velocity x time), providing exact location (using relative distance to satellites), precise maps, and navigation. In 1989, Magellan Systems Corporation, based in San Dimas, California, was the first company in the world to introduce a portable GPS receiver for civilians called the NAV 100. This led to a boom in the GPS market. Finally, the control segment consists of a worldwide control station that makes sure that the satellites are in proper position.

The U.S. Air Force develops, maintains, and operates the space and control segments of GPS. The system became available to civilians in 1983 after a Korean

passenger jet unintentionally entered prohibited Soviet airspace and was shot down by a Soviet aircraft, resulting in the death of the passengers. The U.S. government acknowledged that this accident could have been avoided if GPS technology had been available. President Ronald Reagan announced that GPS technology would be available to civilians, and it is now freely available to anyone on a global scale. The military services are available to U.S. government and allied forces. Military and civilian access to GPS is different; the civilian version of GPS is much less complicated and lower in accuracy. GPS technology is constantly updated. It provides 24-hour data that is extremely accurate in providing three-dimensional location information, including longitude, latitude, and altitude. It also provides the user with accurate speed and time.

GPS was originally called Navstar GPS. It was a project by the U.S. Department of Defense launched in 1973 for U.S. military use but did not become fully operational until 1995. GPS is not the only system of its kind, although it is the prominent one. Other systems are in use or under development by other countries, mainly because it is U.S. property, and the American government and military have the power to deny access to any opposing forces. This happened to the Indian military in 1999 during the Kargil War.

Some of the other current GPS systems operating around the world are Russia's Global Navigation Satellite System (GLONASS), Europe's Union Galileo Positioning System, China's BeiDou Navigation Satellite System, India's NAVIC, and Japan's Quasi-Zenith Satellite System. GPS was created using information from previous systems that were less functional and with engineering design studies that took place in the 1960s. The system was originally designed with references to similar radio navigation systems used by the British Royal Navy during World War II such as the loran and Decca Navigator.

GPS is a technology that once began as a military weapon and has become part of everyday civilian life. GPS technology has been a major influence on the rise of many different markets and has become a market of its own. The availability of GPS to the public has revolutionized life. Today, civilian GPS receivers, most commonly found in smartphones, are used to navigate anywhere, to check traffic in real time, and to explore

places near or far away. As GPS technology rapidly continues to be updated, we can expect to continue incorporating receivers into new technological gadgets.

Jatziri Hernandez

See also Apollo Project; Drones; National Aeronautics and Space Administration (NASA); Satellites and Space Probes; Skylab; Voyager Spacecraft; *Vol. 1, Sec. 1: Astronomical Almanacs*; *Vol. 1, Sec. 3: Equatorial Sextant*; Solar Compass; Telegraph; Transatlantic Cable; *Vol. 2, Sec. 2: Radio*; *Vol. 2, Sec. 3: Atomic Bombs/Nuclear Weapons*; Military Technology (World War II); Radar; SONAR; *Vol. 3, Sec. 2: Computer/Information Technology*; Mobile Phone; Satellite Radio; Solar Energy; *Vol. 3, Sec. 3: International Space Station*; Smartphone and 3G Network

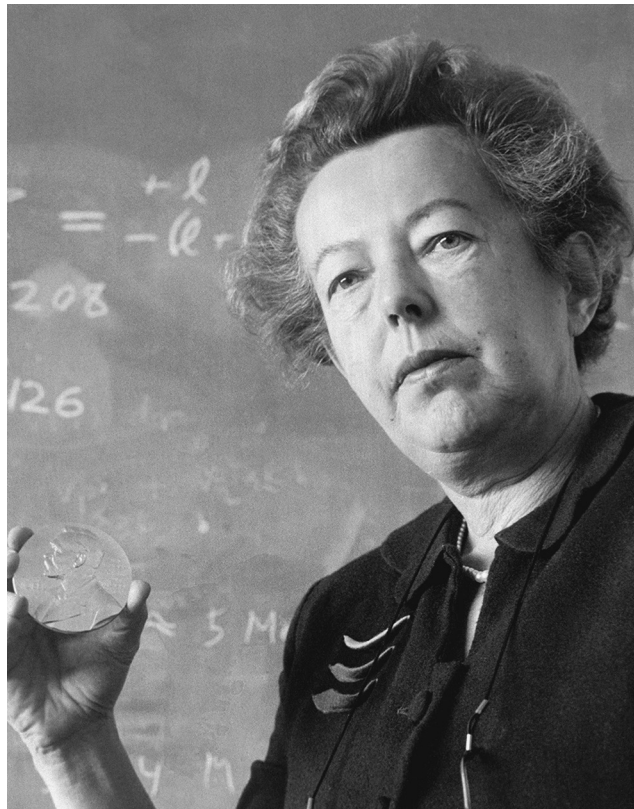
Further Reading

- El-Rabbany, Ahmed. 2006. *Introduction to GPS: The Global Positioning System*. Norwood, MA: Artech House.
- Kaplan, Eliot, and Christopher J. Hegarty. 2017. *Understanding GPS/GNSS: Principles and Application*. Boston: Artech House.
- Milner, Greg. 2016. *PinPoint: How GPS Is Changing Technology, Culture, and Our Minds*. New York: W. W. Norton.
- Montenbruck, Oliver, and Peter Teunissen. 2017. *Springer Handbook of Global Navigation Satellite Systems*. Zurich, Switzerland: Springer International.

Goeppert-Mayer, Maria (1906–1972)

In 1963, Maria Goeppert-Mayer won the Nobel Prize in Physics for describing the nuclear shell model for the atomic nucleus. She was the second woman to win the award. Goeppert also developed the two-photon absorption theory and contributed to the Manhattan Project.

German theoretical physicist Maria Goeppert-Mayer gained her PhD in Germany in 1930. She then moved to the United States with her husband, where she worked on the Manhattan Project, which produced the first atomic bomb. Maria Goeppert was born on June 28, 1906, in Kattowitz, Prussia (now Katowice, Poland).



Physicist Dr. Maria Goeppert-Mayer, who became the second woman in history to win a Nobel Prize, holds the Nobel medal she won in 1963 for her work in atomic physics. (Bettmann/Getty Images)

In 1910, her family moved to Göttingen, Germany, so her father could teach pediatric medicine at the university. Because of her father's status, as a child, Goeppert was able to enroll in some of the best schools. She passed the entry exam for Göttingen University in 1924.

Originally, Goeppert entered the university as a mathematics major, working with Amalie "Emmy" Noether, a noted mathematician. After witnessing a lecture by Max Born on the early discoveries of quantum mechanics, Goeppert became inspired to study physics. Later, Born would oversee her doctoral dissertation on two-photon absorption. Goeppert's thesis was far ahead of its time. Although her photon theory could not be tested until lasers were invented, Goeppert's thesis was considered groundbreaking work.

In the late 1920s, Goeppert met Joseph Edward Mayer, an American physics student studying at Göttingen. They married in 1930. After graduating that same year, Mayer was hired at Johns Hopkins University in

Baltimore, Maryland. Goeppert-Mayer went with him to America. The Great Depression and her gender limited her ability to work. Johns Hopkins University had strong rules against hiring spouses, but the Physics Department allowed her to use its laboratories for free. Unpaid, she worked with graduate students on their dissertations.

In 1941, Goeppert-Mayer found her first job teaching physics at Sarah Lawrence College in New York City. Through connections she had made over the years, she was offered a second job with Columbia University's Substitute Alloy Material (SAM) Project. The SAM Project was a cover for the Manhattan Project, and Goeppert-Mayer's assignment was to help refine uranium ore for its destructive isotopes and to study its thermodynamic properties.

In 1946, Goeppert-Mayer and Mayer moved to Chicago. Goeppert-Mayer worked for the Atomic Energy Commission at the Argonne National Laboratory. She also volunteered her time at the University of Chicago, where Mayer worked as well. There, Goeppert-Mayer became interested in the origin of the elements. After reading through decades of research and studies by other scientists, she noticed that several numbers kept reoccurring—2, 8, 20, 28, 50, 82, and 126. They were dubbed “magic numbers” by Eugene Wigner a few years before and were often associated with the numbers of protons, electrons, and neutrons inside an atom.

Goeppert-Mayer worked on developing a mathematical model of why these numbers were so magical and stable. She developed the nuclear shell model to explain why some numbers were more stable than others. The nucleus, according to her, was a series of “shells” (layers) where protons and neutrons coupled up. As these particles bind to each other, they orbit clockwise within the nucleus while spinning in a counterclockwise direction. Finally, the nucleus can hold twice as many particles as long as the second set of proton/neutron couplings orbits counterclockwise while spinning clockwise. Goeppert-Mayer made the analogy that her model was a ballroom dance, with particles dancing with other particles in an intricate ballet.

When Goeppert-Mayer presented her findings to the science journal *Physical Review*, the editor informed her that the journal had just received a nearly identical paper on the topic. A team of German scientists had

independently reached the same conclusion on the nuclear shell model. Goeppert-Mayer contacted the team leader, J. Hans D. Jensen, to discuss their ideas. The two published their book, *Elementary Theory of Nuclear Shell Structure*, in 1950. In 1963, Goeppert-Mayer, Jensen, and Wigner received the Nobel Prize in Physics for their work. Goeppert-Mayer was the only woman besides Marie Curie to win a Nobel Prize.

Goeppert-Mayer and Mayer moved to San Diego, California, in 1960. They worked together at the University of California, San Diego. Shortly after arriving, Goeppert-Mayer suffered a stroke. Although she continued to research and teach at the university, her health gradually declined. Goeppert-Mayer died on February 2, 1972.

Elliott Popel

See also Carson, Rachel; Lacks, Henrietta; *Vol. 1, Sec. 3*: Mitchell, Maria; *Vol. 2, Sec. 2*: Noether, Amalie Emmy; *Vol. 2, Sec. 3*: Mead, Margaret; Wu, Chien-Shiung

Further Reading

Sachs, Robert G. 1979. *Maria Goeppert Mayer, 1906–1972*. Washington, D.C.: National Academy of Science.

Graham, Bette (1924–1980)

Inventor Bette Nesmith Graham invented Mistake Out, a product generically called “white-out.” Her invention has helped many people save paper and time. She sold her company to Gillette Corporation 1979 for \$47.5 million.

Bette Nesmith Graham was born in Dallas, Texas, in 1924. Graham did not graduate from high school; instead, she went to secretarial school. Graham and her husband divorced after his service in World War II, and Graham had to raise her son, Michael, alone. In 1951, Graham became an executive secretary for the chairman of the board of Texas Bank and Trust. Graham was also a hobby painter and earned extra money painting store windows at holiday time.

As a secretary, she had to use an electric typewriter. Graham hated making mistakes on it. When she did, she had to retype the whole paper, because

mistakes couldn't be erased. Many of her fellow workers had the same issue. As a painter, Graham knew that mistakes could be covered up with more paint, and she used this idea to cover up a mistake at the electric typewriter. She invented a formula for the cover up fluid. Many of the secretaries noticed and asked for the formula so they could also use it when they made mistakes.

She decided she could make money from the formula and created a company called Mistake Out in 1956. When she was fired from Texas Bank and Trust for abandoning her duties at work, Graham focused only on her company. She obtained a trademark in 1958 and created a patent to protect her invention. She renamed her invention Liquid Paper and sold it from home. In 1968, she opened up a new plant and sold 1 million bottles. In 1975, she divorced her second husband and opened a 35,000 square-foot headquarters in Dallas.

Graham brought a unique sensibility to her business. She prioritized product quality over profits and practiced a humanistic management style that placed a higher value on employees than do many American businesses. Her company was one of the first to have an in-house child care facility. In 1979, she sold her company to Gillette for \$47.5 million and unfortunately died the year after.

When she died, half of her money went to charities, and the other half went to her son Robert Michael Nesmith, famed as one of the founding members of the pop rock band The Monkees. One of the charities she invested in was the Council on Ideas, a think tank dedicated to finding solutions to world problems. In 1989, Gillette reformulated Liquid Paper to make it less toxic. In spite of the computer and printer revolution, Liquid Paper is still on the market. Liquid Paper and another brand, Wite-Out, sell a total of \$120 million annually.

Wences Jose

See also *Vol. 2, Sec. 3: Lamarr, Hedy*

Further Reading

Camp, Carole Ann. 2004. *American Women Inventors*. Berkeley Heights, NJ: Enslow.

Hamilton, Margaret (1936–)

Born on August 17, 1936, Margaret Hamilton is a computer scientist, a business owner, and systems engineer. Most notably, she is the woman whose programming skills helped take men to the moon. She is also credited with creating the term “software engineering.”

Margaret Hamilton was born Margaret Heafield to Kenneth and Ruth Esther Heafield in Paoli, Indiana. In 1954, she graduated from Hancock High School. Four years later, she received her BA in mathematics with a minor in philosophy from Earlham College. She married her college boyfriend, James Cox Hamilton, and taught math and French in high school while he finished college. In 1958, she relocated and intended to study abstract mathematics at Brandeis University in Boston. She landed what was supposed to be an in-between job at MIT developing software for predicting the weather. Software engineering and computer science were not disciplines that could be studied at universities at the time. Instead, programmers learned on the job through hands-on experience.

On November 10, 1959, Hamilton gave birth to Lauren Hamilton. Being a working mother in the 1960s was not common, and being a woman in her field of work was even less common. Hamilton was seen on many occasions bringing her daughter with her to work. Lauren would sleep on the floor while her mother spent time creating programs.

From 1961 through 1963, she worked on the SAGE project, whose purpose was to create a computer system that could predict and track weather systems using simulators. The SAGE project was later developed for use by the military to detect and prevent potential Soviet air attacks during the Cold War. Hamilton's success on this program that no one had previously managed to create made her the perfect candidate for the lead developer position for the Apollo flight software.

She taught herself how to program computers and became the director of the Software Engineering Division of the MIT Instrumentation Laboratory (which later became known as the Charles Stark Draper Laboratory). She supervised a team of 100 mathematicians, engineers, technical writers, and programmers to develop the software for the Apollo 11 Guidance Computer.

The Apollo Guidance Computer was a chip-based computer with 64 kilobytes of memory and operated at 0.043MHz. The software was designed with the purpose of navigating to the moon and landing on it before navigating its return to Earth. This moon landing was one of the first examples of software playing such a crucial role in the completion of a mission. Because of the very restrictive weight, size, and power requirements, the program designers chose to utilize silicon chips. These were very expensive at the time, with an unknown reliability.

While her daughter, Lauren, was playing with a display-and-keyboard unit on a command module simulator, an error message popped up. Hamilton insisted on adding code to the program to prevent this error during a flight, even though there was no reason that a trained astronaut would ever do what her daughter had done. The idea was deemed unnecessary by NASA because astronauts are trained to be perfect and cannot make any mistakes. Instead, Hamilton was only allowed to add to documentation available to the astronauts and engineers that said, “Do not select P01 during flight.” What she was told many times would never happen *did* happen on the Apollo 8 flight. Without the precautions Hamilton had wanted to program, the navigation data was lost, and the computer would not be able to bring the astronauts home. After nine hours of troubleshooting, MIT coders were able to come up with new navigational data that was uploaded through Houston, bringing the astronauts home safely.

Hamilton is also credited with preventing Apollo 11 from becoming an aborted mission. Three minutes before Apollo 11 landed on the moon, the computers’ alarms went off because they were overloaded by incoming data. Simply put, the system was performing unnecessary tasks and recognized that this was an error. Hamilton’s insistence on the inclusion of a complete recovery program allowed the software to rank and prioritize tasks to stop lower-priority tasks and redirect power to the more important ones. In a letter written to *Datamation* in 1971, Hamilton insisted that the Apollo 11 landing would not have been successful without this programming.

In 1986, Margaret Hamilton became the CEO and founder of Hamilton Technologies Inc., which is based out of Cambridge, Massachusetts, not too far from

where her career began at MIT. According to the official company Web page, Hamilton Technologies was founded “to provide products and services to modernize the planning, system engineering and software development process to maximize reliability, lower cost and accelerate time to market.”

In 1986, she received the Ada Lovelace Award from the Association of Women in Computing. The moon landing had occurred in 1969, but it took over 34 years for NASA to recognize the crucial role that Hamilton played in computer science and taking men to the moon. In 2003, she received the NASA Exceptional Space Act Award. With it came a check for \$37,200. In 2009, she received the Outstanding Alumni Award from Earlham College. Across her career, Hamilton published 130 papers and reports in regard to her involvement with 60 projects and six major programs, all regarding software engineering and systems creation and management.

Thanks to Margaret Hamilton, software engineering has taken humanity beyond Earth’s atmosphere and laid the groundwork for nearly all modern human aspirations.

Amanda Elaine Duran

See also Apollo Project

Further Reading

Shearer, Benjamin F., and Barbara Smith Shearer. 1996. *Notable Women in the Life Sciences: A Biographical Dictionary*. Westport, CT: Greenwood Press.

Wayne, Tiffany K. 2011. *American Women of Science since 1900*. Santa Barbara, CA: ABC-CLIO.

Haynes, Martha Euphemia Lofton (1890–1980)

Martha Euphemia Lofton Haynes was the first African American woman in the United States to earn a PhD in mathematics. Her father, a dentist educated at Spencian Business College (1886) and Howard University’s Dental College (1888), was a civil rights leader in the Washington, D.C., area. Her mother taught kindergarten in the D.C. public schools and raised both Euphemia

and a younger brother, Joseph, after a breakup with her husband in 1897.

Haynes's academic record speaks to her devotion to education, which continued throughout her adult life. She was the valedictorian at the M Street High School (1907) and Miner Normal School (1909) and then earned a BA in mathematics and psychology from Smith College (1914). She earned a master's degree in education from the University of Chicago (1930); her thesis was titled "The Historical Development of Tests in Elementary and Secondary Mathematics." She then earned a doctorate in mathematics from the Catholic University of America (1943). Her doctoral dissertation was titled "Determination of Sets of Independent Conditions Characterizing Certain Special Cases of Symmetric Correspondences." Her advisor was Aubrey Edward Landry, who is noted in the Mathematics Genealogy Project to have supervised at least two other successful female doctoral students, one as early as 1917. Haynes compared two methods of counting correspondences of rational curves in the projective plane, combining concepts from calculus and linear algebra.

As she pursued her degrees, Haynes taught in the District of Columbia school system, including at the elementary school, high school, and college levels. As a professor at Miner Teachers College in 1930, she created the Mathematics Department and served as its head for 30 years. Miner Teachers College was founded in 1851 as the Miner Normal School for Colored Girls. The school, though originally a primary school, began specializing in teacher training for black women not long after its founding. While Haynes was teaching, the school was part of the District of Columbia's racially segregated public school system. By the time Haynes retired in 1959, Miner Teachers College collaborated with Wilson's Teachers College to become the District of Columbia Teachers College. In 1976, that iteration of the college was absorbed into the University of the District of Columbia.

Haynes served as a member of the District of Columbia Board of Education from 1960 to 1968 and presided as its president from June 1966 to July 1967. During the civil rights era of the 1960s, Haynes advocated for poor students and fought policies that tracked African American students into vocational rather than academic programs.

Haynes was also involved in many community activities. She served as first vice president of the Archdiocesan Council of Catholic Women, as chair of the Advisory Board of Fides Neighborhood House, on several committees on social welfare, on the local and national committees of the United Service Organization, and as a member of the National Conference of Christians and Jews, the Catholic Interracial Council of Washington, the Urban League, the NAACP, the League of Women Voters, and the American Association of University Women. Haynes was awarded the Papal Medal—Pro Ecclesia et Pontific from the Catholic Church in 1959.

Haynes married Harold Appo Haynes (1889–1978) in 1917. Her husband, whom she had known since grade school, earned a doctorate in education from New York University (1946) and taught at Howard University from 1912 to 1918 before teaching and administrating in the District of Columbia School System. He died in 1978 at 89 years old. Euphemia Haynes died on July 25, 1980. Her obituary appeared in the *Washington Post*. The couple had no children. Haynes willed \$700,000 from her estate to the Education School at the Catholic University of America. Much of what we know about Haynes is contained in an archive of her personal and professional papers held at the American Catholic History Research Center and University Archives. Her achievements remain particularly notable because she became a professional mathematician at a time when not only women but also people of color were discouraged from studying math.

Rachel Levy

See also Association for Women in Mathematics (AWM); Goeppert-Mayer, Maria; *Vol. 2, Sec. 1*: Harvard Computers; *Vol. 2, Sec. 2*: Noether, Amalie Emmy

Further Reading

Henrion, Claudia. 1997. *Women in Mathematics: The Addition of Difference*. Bloomington: Indiana University Press.

Kenschaft, Patricia Clark. 2005. *Change Is Possible: Stories of Women and Minorities in Mathematics*. Providence, RI: American Mathematical Society.

Hoover, Erna. See Telephone Switching, Computerized

Hopper, Grace (1906–1992)

Mathematician and U.S. Navy rear admiral Grace Murray Hopper was a pioneer in computer science. Hopper was one of the first programmers of the Harvard Mark I computer and developed the first compiler for computer programming language. She helped to create UNIVAC I, the first commercial electronic computer, and the naval applications for COBOL, or “common business-oriented language.” She is credited with popularizing the term “debugging.” Her nickname, “Amazing Grace,” came from the scope of her accomplishments and her naval rank.

Hopper was born Grace Brewster Murray in New York City in 1906. Her mother, Mary Van Horne, inspired her daughter’s passion for mathematics. When Hopper was seven years old, she took apart all of the alarm clocks in the house to find out how they worked. She was accepted at Vassar College in 1924 and studied mathematics and physics, graduating in 1928 with a bachelor’s degree in these subjects. She earned her master’s degree from Yale University in 1930 and married James Foster Hopper, a professor at New York University. Grace Hopper returned to Vassar in 1931 to teach mathematics, and three years later, she earned a PhD in mathematics from Yale. The marriage was less successful than Hopper’s career. James died during World War II, and the couple had no children.

In 1943, Hopper took a leave of absence from Vassar and joined the U.S. Navy Reserve. She was one of many women who volunteered to serve in the WAVES, or Women Accepted for Voluntary Emergency Service. Hopper graduated first in her class at the naval training school and then went to the Bureau of Ordnance Computation Project at Harvard, where she worked on developing the first electronic computer.

After the war, Hopper resigned from active service. In 1947, Hopper found a moth inside a Mark II Aiken relay calculator, which she and other operators saved and taped into the computer log with a notation that they had “debugged” the system. While Hopper is



Admiral Grace Hopper created the first compiler, invented the computer language COBOL, and helped develop the UNIVAC I and II. After she retired with the rank of admiral in 1986, the U.S. Navy named a missile destroyer in her honor. (U.S. Department of Defense)

generally credited with coining the term, the terminology of computer bugs had been around since Thomas Edison’s time. In an interview, Hopper said that she saved the moth and used the language because it fit into the existing lexicon.

Hopper remained at the Harvard Computation Lab until 1949, turning down a full professorship at Vassar to work as a research fellow at Harvard. In 1949 with the Eckert-Mauchly Computer Corporation, she worked as a senior mathematician on the team that developed UNIVAC I. In 1952, she started and accomplished her work on creating an operational compiler. This was innovational at the time, because it was widely believed that computers could be used only for arithmetic. In 1959, she served as the technical consultant for the committee, which defined the new computer language COBOL. It was Hopper’s belief that

programs should be written in a way that was more similar to English rather than machine code so that it was more accessible.

Hopper retired from the U.S. Navy Reserve as a commander when she was 60 years old. She was recalled to active duty to become director of the Navy Programming Languages Group. She retired again in 1971 but was again asked to return to active services in 1972 and was promoted to captain in 1973. In 1983, she was promoted to commodore by a special presidential appointment and was made rear admiral two years later. When she retired from the U.S. Navy in 1986 at 79 years old, she was the oldest active-duty officer in the navy.

Hopper continued to work in the computer industry until her death. She died in her sleep in 1992 and was interred with full military honors in Arlington National Cemetery. She is remembered as an innovative thinker for whom “we have always done it that way” was a poor reason to do anything. She was also a visionary who could see that computers could have much wider usage if programmers could create tools to make machines user-friendly. In that view Hopper must be credited as one of the people who made the 21st century’s easy-to-use personal computing devices possible.

Peg A. Lamphier

See also Brown, Marie Van Brittan; Goeppert-Mayer, Maria; *Rocket Girls of JPL*; Vol. 2, Sec. 2: Noether, Amalie Emmy; Vol. 3, Sec. 2: Computer/Information Technology; Vol. 3, Sec. 3: Java

Further Reading

Billings, Charlene W. 1989. *Grace Hopper: Navy Admiral and Computer Pioneer*. Hillside, NJ: Enslow.
Williams, Kathleen Broome. 2001. *Improbable Warriors: Women Scientists and the U.S. Navy in World War II*. Annapolis, MD: Naval Institute Press.

Hydraulic Fracturing (“Fracking”)

The development of Marcellus shale into natural gas after 2007 relied on a number of new and emerging technologies. In each case, these innovations helped energy companies to transform a well-known

geological formation—shale layers deep below Earth’s surface—into natural gas that might be harvested and used as a relatively clean alternative to many other fossil fuels. Although this process might appear sensible and straightforward, one of these technologies—hydraulic fracturing—makes harvesting gas from shale deeply controversial.

The debate over hydraulic fracturing (or “fracking,” as it is also called) is focused on states currently working to harvest gas from the Marcellus shale formation, which is located primarily in the Mid-Atlantic region of the United States. Although there are a variety of problematic critiques related to fracking, its threat to underground water supplies may be the most acute. Unfortunately, threats to water supplies are an intrinsic portion of the fracking process.

The remarkable ability to frack deep below Earth’s surface begins with horizontal drilling. In the late 20th century, most oil and gas wells were drilled as vertical holes down through rock formations such as the Marcellus. Although a vertical gas or oil well could drain an area of about 10 to 40 acres, dense rock such as shale does not release its fluid or gas from a vertical hole drilled through it. Even though the Marcellus shale can be more than 900 feet thick, it does not achieve sufficient profile to release a significant amount of gas. Horizontal drilling creates a hole several thousand feet horizontally across the shale. After horizontal drilling creates such a hole, a hydraulic fracturing job, or frack job, is done on the newly drilled well. These technologies continue to evolve, and their product is therefore referred to as “unconventional” natural gas.

After casing or heavy pipe has been run into the newly drilled hole to line it, extremely high-pressure pumps are hooked up, and fluids (mostly water and sand) are forced down into the shale to open cracks and fissures so that more natural gas can flow out of the formation. The fractures allow the gas to seep into the well bore for collection. When the gas is produced in the shale and becomes pressurized, the pressure splits the rock. The Marcellus shale is chock-full of natural fractures, making it easier for gas companies to extract gas. “Fractures are good for business,” says one industry scientist. “If you have enough natural fractures, it’s much cheaper to drill a production well than if you do not have them.”

Hydraulic fracturing is the primary completion process used in the Marcellus shale. It has been the subject of controversy lately, with environmental groups protesting the drilling of new wells in the environmentally sensitive Chesapeake Bay watershed, among other areas. Wells in the Marcellus formation are as deep as 9,000 feet, and the productive zone is far below any water aquifers. A properly cased gas well, lined with thick steel pipe and cemented into place, will ensure a safe frack job. State and federal agencies monitor the process of casing and testing new wells and hydraulic fracturing. The source of contention among environmental groups is the number of chemicals pumped into the formation along with frack water and sand. Up to 50 percent of this fluid may remain in the ground; however, it may take millions of years for any of it to migrate upward to water-bearing zones. If proper safety measures are undertaken, hydraulic fracturing can be a safe means of producing Marcellus shale gas wells.

The impact of hydrofracking on surface water and groundwater is cause for great concern. About 5 million gallons of water per well are used to make fracking fluid, a mixture of water, sand, and hundreds of other possible chemicals, including such hazards as benzene, formaldehyde, arsenic, and diesel fuel. Some frack water stays in the ground, and some is returned to the surface.

This flowback accumulates higher concentrations of salts and minerals and sometimes radioactive contamination. Wastewater treatment plants cannot remove many of these pollutants. Some flowback is reused for fracking, but more is stored in huge artificial ponds. Spills occur during water transport and storage. Improperly cased wells leak frack water and methane into the water table, polluting public and private wells. Pennsylvania waterways drain into the Chesapeake Bay, so gas drilling increases the bay's pollution problems. Storm water erosion carries increased silt loads from dirt roads and drill sites. Minerals from frack water discharged into streams and rivers increase total dissolved solids in the bay.

Some regulations are in place to reduce the problems caused by drilling for shale gas. New laws are being proposed and vigorously debated.

Currently in Pennsylvania, setbacks are required between gas wells and water sources. Drillers must acquire permits, submit plans, post bonds, and notify

landowners whose water supply is within 1,000 feet of a gas well. Gas wells must be cased to prevent contamination of the groundwater table. Pennsylvania's Oil and Natural Gas Act prevents local municipalities from regulating drilling activities but allows local zoning of well placement.

In 2010, a bill proposed the repeal of exemptions from clean water and environmental impact regulations allowed to gas drillers by the 2005 Federal Energy Policy Act and required disclosure of frack water chemicals, but the bill died in committee. In 2011, SB 1100 proposed somewhat stiffer requirements to safeguard water sources and surface owners' rights and requires impact fees to mitigate landowner and community problems. The bill imposes no gas revenue tax, contrary to the wishes of most Pennsylvanians.

The history of coal mining shows the long-term costs of shortsighted extraction policies. Pennsylvania alone has 9,000 abandoned mines and acid mine drainage that pollutes 2,500 miles of streams. The projected cleanup cost is \$15 billion. Awareness of these consequences can help Pennsylvanians choose better ways to benefit from our newest energy boom.

Brian C. Black

See also Petroleum Industry (Post–World War II); *Vol. 2, Sec. 2*; Petroleum Industry (Pre–World War II); *Vol. 3, Sec. 2*; Solar Energy; Wind Energy

Further Reading

Andrews, Anthony. 2010. *Unconventional Gas Shales*. Washington, D.C.: BiblioGov.

McGraw, Seamus. 2011. *The End of Country*. New York: Random House.

Penn State Marcellus Center for Outreach and Research. <http://www.marcellus.psu.edu/>, accessed September 25, 2018.

Hydrogen Energy

Hydrogen is considered the simplest element and is one of the most abundant elements in the earth's crust. It composes about 75 percent of the universe. Natural hydrogen never stands alone; it is always associated with other natural elements. Hydrogen has the highest energy of any common fuel by weight but the lowest

energy content by volume. It is also the lightest element. To get energy from hydrogen, we have to mix it with oxygen to create a chemical reaction, which then creates hydrogen energy.

Fuel cells convert the chemical energy in hydrogen to electricity, with pure water and heat as by-products. Fuel cells are known to be up to three times more efficient than other traditional technologies, which usually generate around 35 percent of the energy of fuel cell systems, up to 60 percent. Fuel cells continue to produce energy as long as hydrogen is supplied, but they work best with pure hydrogen. Also, fuel cells work quietly, have fewer moving parts, and pollution is lower with them, because the system is pollution free. Fuel cells can power anything that batteries can power.

Since the 1970s, the NASA program has relied on hydrogen gas for rocket fuel to take crews and cargo into space. The space program used liquid hydrogen to power the electrical systems of shuttles as well as to launch them and other rockets into orbit. One program used around 500,000 gallons of cold liquid hydrogen with other operations to burn rocket engines of each shuttle flight. Fuel cells were one component of powering space shuttles, contributing to the production of a clean by-product—pure water—for the shuttle crew.

Claudia Garcia

See also National Aeronautics and Space Administration (NASA)

Further Reading

Backus, Albert O. 2006. *Hydrogen Energy: Background, Significance and Future*. New York: Novinka.

Tapan, Box, and Pierre Malbrunot. 2014. *Hydrogen*. Montrouge: John Libbey Eurotext.

IBM 360 Computer

The 1964 New York World's Fair would be the launching point for a revolution in business computing. The crown jewel of the IBM pavilion was the million-dollar-plus IBM 360 computer and a dramatic introduction of the computer to the general public. The IBM 360 family of computers was designed to do a

variety of tasks for businesses, including administrative and engineering tasks. IBM promised basic software that allowed for future upgrades. This common instruction-set architecture was revolutionary for the time and is taken for granted today.

The IBM pavilion at the World's Fair had a 500-seat theater on hydraulic lifting rams, pushing the audience to the rooftop to view a nine-screen film on the workings of a computer. The fair had over 10 million visitors. The exhibit allowed the first interaction with a computer for members of the public. Questions about history were asked for the computer to respond to. The development costs of the IBM 360 computers were in the billions, exceeding the development costs for the nuclear bomb. IBM believed the 360 series would open up the commercial market for the computer, which had been dominated by government and military contracts. It was an investment that would assure IBM's dominance in business computers for decades. The original price for units ranged from \$135,000 to \$500,000. The first commercial customers were insurance companies, banks, and the accounting departments of large manufacturing companies such as United States Steel.

While the IBM 360 was a revolutionary product, it was an evolutionary result of IBM's business model. In fact, IBM's business model has been one of evolving business machines for decades, moving from hand calculators to electromechanical devices to electronic calculators. IBM had a long history in data analysis and business calculations going back to the 1890 census. Herman Hollerith had designed a punched data card to tabulate experimental counts for the 1880 Tabulating Machine Company. The company won government contracts to analyze census data but looked for commercial business applications for the machines at companies such as the railroads. In 1914, Thomas Watson was brought in from National Cash Register to head the then Computing Tabulating Recording Company. The company had been formed in 1911, which is the official formation date of IBM; its name was changed to International Business Machines Corporation in 1924. In 1920, IBM introduced its first machine—the printing tabulator.

Like high-tech companies today, IBM formed educational and creativity programs for employees to

develop new products. By the 1930s, IBM was making time clocks, job recorders, time stamps, and dial recorders. In 1935, IBM won the contract for the world's biggest accounting project, known as the Social Security Act, using its "super-computing machine." IBM had also introduced the first electric typewriter, which would be a core product for the company for decades. These two technologies would be key roots of the evolution of the IBM 360.

These technologies were merged to create the first electromechanical calculator in the late 1930s. During World War II, IBM invested heavily in research, resulting in the release of the IBM 603, the first commercial product to use electronic arithmetic circuits. In the 1950s, IBM started using magnetic tape as storage for its calculators. While large computers such as the Universal Automated Computer (UNIVAC) were focused on specific applications, IBM wanted flexibility in its large computers. A programming language known as FORTRAN was released in 1957, allowing the computer to be used for different operations based on formula calculations. This would be a key evolutionary step in the development of the IBM 360.

The 1960s brought huge investment in research and development, which resulted in applications such as its report program generator. The 1962 IBM 7090 was developed to help airlines manage their reservation systems. The work on this project would lead to the IBM 360. IBM was then the largest computer company in the world, with over 100,000 employees, and it controlled 70 percent of the market. The company was gambling billions in research for its IBM 360 system. The competition of Burroughs, National Cash Register (NCR), Eckert–Mauchly Computer Corporation (makers of UNIVAC), Control Data, General Electric, Radio Corporation of America (RCA), and Honeywell, known as the "seven dwarfs," were letting IBM take the research lead. The research-and-development costs for the IBM 360 are still considered the highest for any product development project by a private company. Many inside IBM thought the IBM 360 would never recoup the huge investment. The risk was really overstated, since IBM had been taking steps toward the IBM 360 for over 50 years. Its evolutionary-step research business model would become the standard for corporate research

managers. Using this approach to research a project would produce a development tree of new products.

The IBM 360 would be a huge success, and research on the project would lead to the magnetic tape typewriter, NASA computer systems, memory chips, and fractals, which would lead to computer animation. The IBM 360 became the heart of America's space program. It found a home in most of America's accounting and engineering departments. IBM sales increased more than fivefold. The company was so dominant that its architecture became a standard. The cloning of the IBM 360 by Soviet spies assured that the IBM architecture would become a world standard. The IBM 360's success brought the number of company employees to 270,000 and its sales to over \$7 billion by 1970.

The gigantic success of the IBM 360 would bring a new problem. The U.S. government filed an antitrust suit in 1969, stating that IBM had violated the Sherman Anti-Trust Act. The case would drag out for 13 years (*United States v. International Business Machines Corp.*) and impact IBM's managerial and product decisions. Eventually, the government dropped the case, but IBM did open its systems and training up to allow the development of independent companies to provide services for IBM hardware. With its failed entry into the copier market, IBM showed that size alone did not guarantee new product success. Finally, in the 1980s, Apple and Microsoft took down the giant of the PC business.

Quentin R. Skrabec

See also Commodore 64; Fortran; *Vol. 3, Sec. 2*: Apple II; IBM Personal Computer

Further Reading

- Austrian, Geoffrey. 1982. *Herman Hollerith: Forgotten Giant of Information Processing*. New York: Columbia University Press.
- Maney, Kevin. 2004. *The Maverick and His Machine: Thomas Watson, Sr. and the Making of IBM*. New York: Wiley.
- Pugh, Emerson. 1995. *Building IBM: Shaping an Industry and Its Technology*. Cambridge, MA: MIT Press.

In Vitro Fertilization (IVF)

In 2010, Robert Edwards won the Nobel Prize in Physiology or Medicine for the development of in vitro fertilization (IVF). Although the prize was ultimately awarded to a British scientist, the development of IVF was an international endeavor that required collaboration between scientists from England, Australia, and the United States.

In 1965, Edwards, working with a married pair of United States scientists, Georgeanna Seegar Jones and Howard Jones at Johns Hopkins Hospital, published their attempts to fertilize human ova in vitro. Edwards also worked with Patrick Steptoe, a gynecologist working the United Kingdom, to develop a less invasive laparoscopic surgery to harvest mature human eggs. Edwards's collaboration with Steptoe produced a fertilized human egg in vitro.

Implantation studies began in 1973, when Carl Wood and John Leeton of Australia reported the first human IVF pregnancy—which resulted in early miscarriage. In the same year, American scientists Landrum Shettles and William Sweeney attempted IVF in an infertile couple, Doris and John Del-Zio. Eggs and sperm were harvested and combined, but hospital administration prevented Shettles from implanting the embryos. Doris Del-Zio later sued the hospital for “intentional infliction of emotional distress.” The U.S. government subsequently passed legislation preventing IVF research pending approval from a National Ethics Advisory Board. Funding for IVF research did not continue until March 1979.

Edwards and Steptoe continued their work in the United Kingdom and, in 1978, their work produced the first-ever IVF birth when baby Louise Brown was born in Oldham, England, on July 25, 1978. In 1981, Howard and Georgianna Seegar Jones of Eastern Virginia Medical School achieved the first IVF birth in the United States: Elizabeth Carr. Their technique, called “controlled ovarian hyperstimulation” (COH), used hMG, a follicle-stimulating hormone that increased the production of oocytes.

By 2006, IVF, also called assisted reproductive technology (ART), produced 54,656 infants, or 1 percent of total U.S. births. In 1984, Jones helped establish an ethics panel to guide its practices, and it is now part of the American Society for Reproductive Medicine.

Georgianna died in 2005. By the time Jones died in 2015, about 4,000 IVF babies had been born with assistance from the clinic the Joneses established, and fertility treatments there have helped thousands of other families.

Lynda C. Titterington

See also Vol. 3, Sec. 2: Robotic Surgery

Further Reading

Edwards, R., and P. Steptoe. 2013. *A Matter of Life: The Story of IVF—A Medical Breakthrough*. London: Finestride & Crownchimee.

Jones, H. W. 2014. *In Vitro Fertilization Comes to America: Memoir of a Medical Breakthrough*. Williamsburg, VA: Jamestowne Bookworks.

Integrated Circuit

The integrated circuit, invented in 1958 and commonly known as the microchip, revolutionized electronics, making possible modern digital technologies.

Before the integrated circuit, the electronics industry relied on vacuum tube technology. But vacuum tubes presented many difficulties: they were easily broken, bulky, unreliable, power hungry, and produced considerable heat. In 1947, Bell Telephone Laboratories developed the transistor, which overcame many of the drawbacks of vacuum tubes. In comparison to vacuum tubes, transistors were sturdy, compact, more reliable, more energy efficient, and produced less heat. Engineers were able to design more complex electronic circuits with hundreds or thousands of discrete components such as transistors, diodes, rectifiers, and capacitors. However, these components still had to be interconnected to form electronic circuits, and hand-soldering individual components to tiny bits of wire was expensive and time-consuming. Also, each of these soldered joints could potentially be compromised, causing a circuit to fail.

Jack Kilby, an electrical engineer at Texas Instruments, took on the challenge of finding a cost-effective, reliable way to produce and interconnect these components. In 1958, he developed the first working integrated circuit. Instead of using separate transistors, resistors, and capacitors to form a circuit, Kilby's

integrated circuit combined a transistor, a capacitor, and the equivalent of three resistors all on the same chip. This first integrated circuit utilized a thin slice of germanium as a bulk resistor and contained a single bipolar transistor. It had four input-output terminals, a ground, and wires composed of gold. Kilby fabricated three types of circuits to test his idea: a flip flop, a multi vibrator, and a phase shift oscillator.

While Kilby was developing his integrated circuit technology, Robert Noyce of Fairchild Semiconductor was also working on a solution. His approach was to use a photolithographic printing technology known as the planar process, which made his circuit easier to manufacture than Kilby's. Noyce's invention debuted five months after Kilby was issued his patent for the integrated circuit. In 1959, both Kilby and Noyce were named as inventors of the integrated circuit in their companies' applications for patents. Years of litigation resulted in Fairchild and Texas Instruments agreeing to cross-license their technologies.

Without the integrated circuit, which has been called the single most important invention of the information age, computer technology as we know it now would not be possible. Microelectronics are the basis for all modern technology, powering desktop, laptop, and mainframe computers as well as communications equipment and controlling everything from cars to advanced machinery. Internet technology is dependent on the integrated circuit for high-speed digital communications, satellite transmissions, and multifunctional wireless handheld devices.

Terry Steagall

See also Intel Corporation; Kilby, Jack; Noyce, Robert

Further Reading

Reid, T. R. 2001. *The Chip: How Two Americans Invented the Microchip and Launched a Revolution*. New York: Random House.

Intel Corporation

Founded in 1968, Intel Corporation is an American multinational technology company based out of Santa Clara, California, in the heart of Silicon Valley. Founded by Gordon Moore and Robert Noyce, Intel

Corp. is the world's largest producer of semiconductor chips and the inventor of the most common processing chip found in most personal computers. Lenovo, Apple, Dell, and HP are a few of the examples of computer companies that Intel Corporation supplies with chips. In addition to processors, Intel also manufactures motherboard chipsets, network interface controllers, graphic chips, and many other products as well as communications and computing devices.

Intel Corporation was founded on July 18, 1968, by Robert Noyce and Gordon Moore. A chemist who, along with seven other men, had founded Fairchild Semiconductor 11 years before Intel, Moore served as Intel's first executive vice president. Moore is the author of "Moore's Law," which says that the number of transistors in a dense integrated circuit will double every two years. Technology companies use Moore's Law to plan long-term strategies in product development. Robert Noyce, another cofounder of Fairchild Semiconductor with Moore, is often cited as the person responsible for the first integrated circuit (microchip). Jack Kilby, who worked at Texas Instruments, is also so credited.

Moore and Noyce also worked with Hungarian American Andrew Grove, noted engineer and businessman. Like Moore and Noyce, Grove worked at Fairchild Semiconductor and left that company along with Moore and Noyce when they began Intel. Andrew Grove was Intel's first director of engineering and helped transform the company into the world's largest manufacturer of semiconductors. Another Hungarian American, Leslie L. Vadasz, made up the fourth of Intel's original employees. He was at the head of the department that developed the Intel 4004, a four-bit central processing unit (CPU) that became Intel's first commercial success in microprocessors.

Arthur Rock provided Noyce and Moore with start-up capital and helped the men find investors. Two years after its founding, the company went public. Originally, the founders planned to call the company "Moore-Noyce," but they feared the name sounded like "more noise," so they took the first letters from "integrated" and "electronics" to make "Intel."

At first the company made semiconductors, but it quickly branched out to SRAM and DRAM memory chips. SRAM and DRAM are types of semiconductor memory that use bistable latching circuitry to store each bit. SRAM displays data remanence—data that is

eventually lost when the memory is not powered. DRAM, on the other hand, is dynamic random-access memory that must be periodically refreshed. SRAM is more expensive than DRAM. SRAM is typically used for computer CPUs to reduce the average cost of access to the main data from the main memory, while DRAM is used for a computer's main memory. SRAM and DRAM represented the majority of Intel's business until 1981.

Intel also created the world's first commercial microprocessor chip in 1971. It was not until the success of the personal computer that chips became its primary business. At first, Intel provided microchips to IBM and then to other companies in the personal computer market. Intel invested a large amount in new microprocessor designs, causing the rapid growth of the computer industry during the 1990s. By marketing their processors under the name "Pentium," Intel developed customer brand loyalty.

In the 2000s, Intel lost its dominance to competitors, particularly Advanced Micro Devices (AMD). Attempts to diversify the company proved unsuccessful.

The company was known for having aggressive tactics in defense of its high market position, often crushing smaller companies with intellectual property rights lawsuits. Even when Intel lost, it won because competitors could not afford the legal fees it took to fight a company as powerful as Intel. AMD has accused Intel of unfair competition and has brought a number of lawsuits against the technology behemoth. Intel has also had several struggles with Microsoft for control over future directions in the personal computer industry.

In 2008, Intel introduced its first solid-state drives (SSDs), solid-state devices that store persistent data (data that outlives the process that made it). Intel continues to improve its SSDs, such as with a 2015 plan to market a consumer PC with an SSD drive. In the 2010s, Intel has made a significant number of corporate acquisitions, including of McAfee computer security and Infineon's Wireless Solutions in 2010, Password Box in 2014, and Vuzix, a "smart glass" company in 2015.

In 2002, President George W. Bush gave Gordon Moore a Presidential Medal of Freedom for his contributions to technology and science, and in 2008, he was inducted into the Computer History Museum. Robert

Noyce died in 1990. The Noyce Foundation provides funding for mathematics and science education for American children.

Rosanne Welch

See also IBM 360 Computer; Integrated Circuit; Kilby, Jack; Noyce, Robert; Silicon Valley; Single-Chip Microprocessor; Vocoder; *Vol. 3, Sec. 2*: Apple; Apple II; IBM Personal Computer; Microchip; Microsoft; Wozniak, Steve; *Vol. 3, Sec. 3*: Linux; Video Game

Further Reading

Burgelman, Robert A. 2001. *Strategy Is Destiny: How Strategy-Making Shapes a Company's Further*. New York: The Free Press.

Jackson, Tim. 1997. *Inside Intel: Andrew Grove and the Rise of the World's Most Powerful Chip Company*. Boston: Dutton Adult.

Malone, Michael S. 2014. *The Intel Trinity: How Robert Noyce, Gordon Moore, and Andy Grove Built the World's Most Important Company*. New York: Harper Business.

Intelsat. See Comsat/Intelsat

Jackson, Mary Winston (1921–2005)

Starting as a "computer" for the segregated, all-black West Area Computing division at Langley Research Center in 1951, Mary Jackson became NASA's first black female engineer. She was recruited by the National Advisory Committee for Aeronautics (NACA) in 1951 for her mathematical knowledge and computation ability. She is notable for breaking social expectations for both women and African Americans. She is also known for her role in promoting women in NASA's science, engineering, and mathematical careers.

Born in Hampton, Virginia, on April 9, 1921, Jackson was the daughter of Ella and Frank Winston. She graduated from the all-black George P. Phoenix Training School with the highest honors and later earned her bachelor's degree in mathematics and



Mathematician Mary Jackson, the first black female engineer at NASA, at work at NASA Langley Research Center in Hampton, Virginia, in 1977. (Bob Nye/NASA/Donaldson Collection/Getty Images)

physical science from Hampton Institute in 1942. After graduating, she became a tutor for high school and college students before being recruited by NACA as a research mathematician, or “computer.” A “computer” was needed to compute and check mathematical calculations used by the Guidance and Navigation Department.

In 1953, she accepted an offer to work for engineer Kazimierz Czarnecki in the Supersonic Pressure Tunnel. Kazimierz was impressed by Jackson’s work and encouraged her to take graduate-level courses to qualify for the open engineering position. Relevant classes at the time were offered only by the University of Virginia, which held night classes at the all-white Hampton High School. Jackson successfully petitioned the City of Hampton to allow her to attend them. After the completion of these courses, Jackson was promoted to aerospace engineer in 1958 and

became the first black female engineer at NASA. Throughout her career, she worked in many divisions, including the Compressibility Research Division, Full-Scale Research Division, High-Speed Aerodynamics Division, and the Subsonic-Transonic Aerodynamics Division.

Jackson achieved the most senior engineering title in her 34 years at NASA but took a demotion to become a manager of both the Federal Women’s Program and the Affirmative Action Program. These roles gave her the opportunity to influence the hiring and promotion of women in STEM careers. Jackson also served as a Girl Scout leader for more than 30 years and is noted for helping children in her community build a miniature wind tunnel for testing airplanes.

Jackson was married and had two children, and she continued her work at NASA until she retired in 1985. This work includes 12 authored and coauthored

technical papers for NACA and NASA and many technical awards, and she advised women and other minorities on career advancement. She died on February 11, 2005, at the age of 83. Her legacy continues today in the 2016 film *Hidden Figures*—which is a recounting of Jackson’s career, specifically on the Apollo missions—and in the career of every female engineer following in her footsteps.

Nicole Curtis-Brown

See also Apollo Project; Johnson, Katherine Goble; National Aeronautics and Space Administration (NASA); Vaughan, Dorothy; *Vol. 2, Sec. 1*: Harvard Computers; *Vol. 2, Sec. 2*: National Advisory Committee for Aeronautics (NACA); *Vol. 3, Sec. 2*: Space Shuttle; *Vol. 3, Sec. 3*: Mars Rover Series

Further Reading

Shetterly, Margot Lee. 2016. *Hidden Figures*. New York: HarperCollins.

Jet Propulsion Laboratory (JPL)

The Jet Propulsion Laboratory (JPL) is a federally funded research-and-development center. It is a part of a public-private partnership with the U.S. government. Its main purpose is conducting research and experiments for the government, which funds it. It is also part of the National Aeronautics and Space Administration (NASA), an independent agency belonging to the U.S. government that conducts research for the U.S. space program and in the aerospace field. JPL currently employs and is operated by many at the California Institute of Technology.

Surprisingly, JPL appeared many years before NASA was even formed. A lot of their research goes toward similar goals. The JPL has two main facilities in La Cañada Flintridge and Pasadena, California. Despite its name, JPL does not mainly focus on jets or propulsion. The lab’s main area of focus is on the development and operation of planetary robotic spacecraft, also known as space probes. Robotic spacecraft are sent from Earth to explore the moon, planets, or other things in the solar system. Their main purpose is to gather information, and they are designed based on

what kind they need to gather and measure. NASA and JPL determine what kind of data they want to research.

The Jet Propulsion Laboratory was almost accidentally created in the mid-1930s. Some rocket enthusiasts, most of whom were students at the California Institute of Technology, began to experiment, leading to an explosion. They moved their work out to La Cañada Flintridge, California, where one of the JPL facilities exists today.

The “Space Race” between the United States and the Soviet Union is one reason that JPL rose to prominence in space exploration. In January 1958, JPL was responsible for creating and launching a spacecraft known as Explorer 1. Working alongside the U.S. Army, JPL created the first-ever American satellite. Ten months later, NASA was founded on October 31, 1958, and the army transferred its work to it.

Since then, JPL has been a part of or led countless space missions. In the early years of space exploration, JPL focused on big missions to reach as far as possible and encounter other planets in the solar system. JPL took part in NASA’s Viking program to Mars, one of our neighboring planets. Spacecraft created by JPL went to Mars to study the planet from both space and the surface. The two space probes each had two parts; two parts would orbit Mars while the other two were on the surface. The two space probes were launched on August 20 and September 9, 1975, respectively. They both reached their destination roughly 10 months later.

These space probes gathered large amounts of new information about Mars. JPL was a part of this mission that would bring the United States more understanding of outer space than ever. The probes took close and clear images of Mars’s surface, addressing perennial questions about life on Mars and whether it could sustain human life. The findings showed that water may once have existed on Mars. The terrain and geological forms indicated that rivers and lakes may once have existed, as huge valleys and canyons were found carved into the ground. The erosion of the landscape resembled the erosion we see here on earth where rivers and streams once flowed.

The Jet Propulsion Laboratory was very successful in its early missions, which encouraged further exploration and elicited excitement and approval from the government and people who wanted to learn more. Another well-known large space mission that JPL developed robotic spacecraft for and involved NASA

was the Voyager Cassini-Huygens project. The craft made its trek to a planet nearly 800 million miles away from Earth: Saturn. Cassini was the name of the spacecraft that would orbit Saturn, and the Huygens was the craft that would land on Saturn and probe it. The spacecraft began development at the Jet Propulsion Laboratory and eventually was launched on October 15, 1997. It finally reached Saturn nearly seven years and three months later on January 14, 2005. This landing would be the first ever of any robotic spacecraft on a planet at the outer layer of the solar system.

JPL's Cassini-Huygens had a few jobs to do. JPL and NASA, as well as a few European countries, wanted to learn as much as they could from Saturn, and the spacecraft they built was perfect for gathering information and data. One of the things people are most curious about are Saturn's rings. NASA and JPL most wanted to understand their structure and behavior. They also wanted to collect information on the atmosphere, weather, and material of Saturn as well as its moons. The probe on the planet communicated with scientists by sending signals to the orbiter, Cassini, and the orbiter relayed the data to Earth. Just over 19 years ago, the Cassini-Huygens spacecraft went to Saturn, and it is still hard at work today, gathering data.

Perhaps one of the most notable and well-known space probes is the Curiosity Rover, also developed with the help of the JPL. In the second decade of the 21st century, the obsession with Mars has been at an all-time high. Did Mars ever have a climate like Earth's? We also want to know if humans can inhabit Mars. The Mars Science Laboratory launched by NASA in late November 2011 is headed by JPL; its goal is to learn about Mars, its geology and climate, and ultimately whether or not water plays a role on the planet. The robotic spacecraft created by JPL scours the landscape of Mars, collecting data. With its computers and cameras the Curiosity Rover communicates in several ways. An X-band system as well as a UHF radio transmit signals that are received on Earth by antennas at the Goldstone Deep Space Communications Complex, which JPL also created. Curiosity's current mission is to gather information on the biological, geological, and geochemical nature of Mars.

The Jet Propulsion Laboratory has contributed greatly to the knowledge and advancements in space

exploration and science that help us understand our solar system and things in it as close as our moon or as far as planets millions of miles away. JPL's work will be valuable even hundreds of years from now. If one day humans inhabit Mars, JPL will have contributed to the possibility. It has allowed us to believe in and do much that we once thought was impossible in regard to exploring our solar system.

Peg A. Lamphier

See also National Aeronautics and Space Administration (NASA); Voyager Spacecraft

Further Reading

- Conway, Erik M. 2015. *Exploration and Engineering: The Jet Propulsion Laboratory and the Quest for Mars*. Baltimore: Johns Hopkins University Press.
- Koppes, Clayton R. 1982. *JPL and the American Space Program: A History of the Jet Propulsion Laboratory*. New Haven, CT: Yale University Press.
- Westwick, Peter J. 2007. *Into the Black: JPL and the American Space Program, 1976–2004*. New Haven, CT: Yale University Press.

Johnson, Katherine Goble (1918–)

Born on August 26, 1918, in White Sulphur Springs in West Virginia, Katherine G. Johnson, née Katherine Coleman, is a remarkable African American mathematician and computer scientist whose life has been punctuated by a series of major breakthroughs and contributions to U.S. aerospace programs.

Johnson exhibited brilliance in mathematics at a young age and, combining that with a love for learning, she graduated early from high school and entered West Virginia State College at 15 years old. She found a mentor in renowned Dr. William W. Schiefflin Claytor, the third African American to earn a PhD in mathematics. He was so impressed by her intelligence and vivid passion that he made it his mission to prepare her to become a research mathematician, designing a class in the analytic geometry of space specifically for her. She graduated at age 18, summa cum laude, with bachelor of science degrees in mathematics and French.

Since the depression still lingered, teaching was the only stable job for educated black women.

Therefore, Johnson joined the workforce as a teacher of math and French. In 1937, she was selected to be one of the three black students to integrate West Virginia's graduate school in Morgantown. However, she opted out of finishing the program because the environment proved unfavorable for her. In 1930, she married James Francis Goble and had three daughters: Joylette, Katherine, and Constance.

In 1952, she found out from a relative that the National Advisory Committee for Aeronautics (NACA) Langley laboratory had open positions at the all-black West Area Computing section. The division was headed by Dorothy Vaughan, a fellow Virginian, and made up of African American women who served as "computers." A computer was needed to compute and check mathematical calculations used by the Guidance and Navigation Department of NACA. She applied for the position and was accepted the following year. She began working there in 1953, and her expert calculations and notable curiosity enabled her to stand out. She not only wanted to do the job but also wanted to know the main reason behind it, asking numerous questions to gain better understanding. She was soon moved from the computing lab to Langley's research division, where she spent the next four years analyzing flight test data. It was in late 1956 that her husband died of cancer, and despite the challenges at home, she succeeded at her job, earning the respect of her male colleagues.

At the beginning of the Space Race in 1958, NACA reformed into the National Aeronautics and Space Administration (NASA). Johnson was one of those assigned the task of determining how to get a human into space and back. She remained a key asset to NASA with her consistent accuracy in trajectory calculations for the historic Apollo 11 trip to the moon and back in 1969, her participation in the development of the Space Shuttle program and Earth Resources Satellite, and other work until her retirement in 1986. Johnson has been presented with an assortment of awards and honorary degrees, including the Presidential Medal of Freedom, the highest civilian honor, by Barack Obama in November 2015. The following May, NASA opened the 40,000-square-foot Katherine G. Johnson Computational Facility at Langley.

Martha Njuguna

See also Jackson, Mary Winston; National Aeronautics and Space Administration (NASA); Ochoa, Ellen; *Vol. 2, Sec. 1: Harvard Computers*; *Vol. 2, Sec. 2: Cannon, Annie Jump*; *Vol. 3, Sec. 2: Space Shuttle*

Further Reading

Shetterly, Margot. 2016. *Hidden Figures*. New York: HarperCollins.

Kevlar. See Bulletproof Vest/Kevlar

Kilby, Jack (1923–2005)

Jack Kilby is best known as the inventor who revolutionized the electronics industry by developing the integrated circuit, or microchip, which allowed computers to become smaller and more affordable, launching the digital age.

Kilby grew up in Great Bend, Kansas. His father ran a small electric company, and Kilby became interested in electronics in high school when his father had to work with amateur radio operators to communicate with isolated customers who had lost power and phone service during an ice storm. He decided to apply to the Massachusetts Institute of Technology's electrical engineering program, but his scores on the entrance exam fell slightly under the cutoff, and so he was unable to enroll. Instead, he joined the army and was stationed at a radio repair shop in northeast India.

After returning from the service, Kilby used his GI Bill to major in electrical engineering at the University of Illinois, graduating in 1947, one year before the invention of the transistor, which would entirely change the direction of electronics innovation.

After his graduation, Kilby first worked for an electronics manufacturer in Milwaukee, Wisconsin, that made radio, television, and hearing aid parts. While working there, Kilby earned his master's degree in electrical engineering. In 1958, Kilby took a position with Texas Instruments, where he was allowed to work in his area of interest—electronic component miniaturization.

During the summer of 1958, the Texas Instruments facility was only sparsely populated because

most of the researchers were on vacation. With few distractions, Kilby had the time he needed to conceptualize the integrated circuit. He realized that all the parts of a circuit, not just the transistor, could be made out of silicon. Basically, the integrated circuit united the three components—a transistor, a capacitor, and the resistors—on the same chip, making it significantly smaller and more easily produced. Kilby's boss authorized him to pursue the idea, and by September 12, Kilby had built a working model. On February 6, Texas Instruments filed a patent for the invention.

Five months after Kilby was issued his patent for the integrated circuit, Robert Noyce of Fairchild Semiconductor also developed a similar device. Noyce's integrated circuit used a photolithographic printing technology known as the "planar process," which made it easier to manufacture than Kilby's—which used germanium and individual wires. In 1959, both Kilby and Noyce were named as inventors of the integrated circuit in their companies' applications for patents. Years of litigation resulted in Fairchild and Texas Instruments agreeing to cross-license their technologies.

After the invention of the integrated circuit, Kilby went on to lead the first groups that incorporated integrated circuits into military systems and computers. He was also involved with teams that invented the handheld calculator, the first widely available consumer electronic to use the integrated circuit, and the thermal printer. In 1970, he worked on a solar power-generating project that incorporated silicon technology.

Kilby served as the distinguished professor of electrical engineering at Texas A&M University from 1978 to 1984. By the end of his career, he held more than 60 U.S. patents. Kilby was awarded the Nobel Prize in Physics in 2000. (Kilby said that he was sure that if Noyce were alive, he would also have been nominated to share the prize.) Other awards included the National Medal of Science and induction into the National Inventors Hall of Fame. Kilby's first simple circuit spawned a world information industries market now worth more than \$1 trillion annually. Kilby died in 2005.

Terry Steagall

See also Integrated Circuit; Intel Corporation; Noyce, Robert; *Vol. 3, Sec. 2: Microchip*

Further Reading

- Kilby, Jack St. Clair. 2001. "Turning Potential into Realities: The Invention of the Integrated Circuit" (Nobel Lecture). *ChemPhysChem* 2: 482–89.
- Reid, T. R. 2001. *The Chip: How Two Americans Invented the Microchip and Launched a Revolution*. New York: Random House.

Kwolek, Stephanie Louise (1923–2014)

Stephanie Kwolek invented a polymer that is manufactured by DuPont under the trade name "Kevlar." After graduating from college, she took what was supposed to be a temporary job at DuPont while saving money to attend medical school. Her work was so interesting, however, that she stayed on with the company and became involved in the research that led to the discovery of low-temperature polymerization. She gained national attention in 1960 for her work creating long molecule chains at low temperatures and her discovery of the method to spin synthetic, petroleum-derived fibers in a liquid crystalline solution. The compound had such high tensile strength that she ran the tests again and again to make sure she had not made an error before reporting her discovery to the laboratory director. The resulting product, Kevlar, eventually led to a multimillion-dollar industry with more than 200 commercial applications, including use in radial tire cords, composites, rope, thermal-insulating clothing, and bulletproof vests. At the time of her retirement, Kwolek owned 17 U.S. patents.

The use of Kevlar in bulletproof vests has earned Kwolek many fans and accolades. More than 2,000 police officers whose lives were saved due to wearing Kevlar vests formed a Survivors Club, a joint venture between DuPont and the International Chiefs of Police Association. Kwolek was regularly contacted by individuals thanking her and even asking for an autograph. Even after her retirement, Kwolek continued to consult with DuPont, as well as to give public and school lectures about careers in science. In 1996, she was featured along with other DuPont employees in a series of print and television ads describing the company's research.

Kwolek was elected to the National Academy of Engineering in 2001 for “the discovery, development, and liquid-crystal processing of high-performance aramid fibers.” She won an early publication prize from the American Chemical Society (1959) and also received the Creative Invention Award of the ACS (1980) and the Perkin Medal of the Society of Chemical Industry (1997), only the second woman to receive that prize. She was inducted into the National Inventors Hall of Fame (1995) and the Women in Technology International (WITI) Hall of Fame (1996). She received the nation’s highest technology honor, the National Medal of Technology (1996), and honorary doctorates from Worcester Polytechnic Institute (1981) and the University of Delaware (2008). She was a member of the American Chemical Society and American Institute of Chemists.

Tiffany K. Wayne

See also Benerito, Ruth Rogan; *Vol. 2, Sec. 1*: Richards, Ellen Swallow

Further Reading

Wayne, Tiffany K. 2010. “Kwolek, Stephanie Louise.” In Tiffany K. Wayne. *American Women of Science since 1900*. Santa Barbara, CA: ABC-CLIO.

Lacks, Henrietta (1920–1951)

Born Loretta Pleasant on August 1, 1920, in Roanoke, Virginia, Henrietta “Hennie” Lacks is known for her “immortal” HeLa (pronounced hee-la) cells that were taken from her without her permission, cultured, and used for research. Lacks died from cervical cancer in 1951, but her cells and her story live on, as does the discussion of medical ethics that surrounds her story.

Lacks came from a poor African American family and was four years old when her mother died. Her father, Johnny, realized that he was not able to take care of all his children on his own, so he sent them to live with relatives. Lacks ended up with her grandfather, Tommy Lacks, who lived in a log cabin, where she had to share a room with her nine-year-old cousin, David “Day” Lacks. Day attended school until third

grade, and Henrietta attended until sixth grade. They worked on their grandfather’s tobacco farm along with many of their other cousins. When Henrietta was 14 years old, she had a child with Day. The couple married in 1941 and had several more children. They also moved to Maryland so Day could work at a steel mill, a job that paid more than sharecropping.

After Henrietta Lacks’s last child was born, she experienced uncontrollable vaginal bleeding. She discovered a lump on her cervix and told Day about it, and they went to see the local doctor. Initially the doctor believed that the lump was from syphilis, but the test for syphilis turned out to be negative. He referred her to Johns Hopkins Hospital, the closest hospital to where the Lackses lived that treated African American patients. Lacks saw gynecologist Howard Jones, who took some tissue samples. In 1951, Lacks was diagnosed with epidermoid carcinoma of the cervix, or cervical cancer.

Jones called his boss, Richard TeLinde, who wanted to compare normal cervical tissue to two types of cancerous tissues. For this, he called the head of tissue culture research at Johns Hopkins Hospital, George Gey. Lacks was an independent woman, so she did not tell her husband that her lump was malignant; she told him that she was going to get treated and would be okay. One of Lacks’s shavings was normal, and the other was cancerous; they were placed in glass dishes and given to Gey so he could try to culture them. It turned out that Lacks’s cancerous cells were able to divide and grow in lab culture material, something no other human cells had ever done.

Scientists were tremendously excited about the research possibilities that could arise from having living cell cultures and began to propagate and sell the HeLa cell cultures to scientists around the nation and the world. Today, there are so many HeLa cells that scientists say that if the cells were lined up end to end, they could to wrap around the earth three times. Lacks’s aggressive cancer killed her just months after her diagnosis on October 4, 1951, at Johns Hopkins Hospital in Baltimore, Maryland. Lacks never knew that her cervical cells had become a commodity, nor did she share in any HeLa profits.

Lacks’s cells have played a crucial role in many scientific breakthroughs. Experimentation on HeLa

cells made it possible for scientists to find cures for some cancers, develop a polio vaccine, learn what happens to cells in space, and more. Nonetheless, Lacks's case illustrates a lapse in scientific ethics in that scientists used her cells without her knowledge or permission, gave her no credit, and allowed her no share of profits from their use. In the 1970s, the HeLa cells came to the Lacks family's attention when scientists asked for more information about their genetics. Racial issues complicated the Lacks case, as critics pointed out that the science and medical fields had a record of abusing African American patients and test subjects. In the 1990s, newspaper articles and a one-hour documentary brought Lacks's case significant attention. Two books further explored the story of both Henrietta Lacks and her HeLa cells. In 1991, the California Supreme Court ruled that it was legal to commercialize a person's "discarded" cells, but scientific ethicists continue to discuss the scientific community's responsibility to test subjects.

Mariana Magaña

See also Carson, Rachel; *Vol. 2, Sec. 3*: Wu, Chien-Shiung

Further Reading

Gold, Michael. 1986. *A Conspiracy of Cells: One Woman's Immortal Legacy and the Medical Scandal It Caused*. New York: State University of New York Press.

Skloot, Rebecca. 2010. *The Immortal Life of Henrietta Lacks*. New York: Crown.

Land, Edwin H. (1909–1991)

Edwin H. Land, best known for his development of the Polaroid camera, was a prolific inventor and businessman who developed optical, photographic, and military devices.

Land attended Harvard University briefly in 1926 but left to pursue research in the field of polarizing optics. The technology he developed, the first inexpensive light-polarizing filter, was initially used in sunglasses and scientific work but was eventually utilized in color animation, camera filters, 3-D movie



Edwin Land, cofounder of Polaroid Corporation, revolutionized in-camera instant photography when he invented inexpensive filters for polarizing light. His Polaroid instant camera made it possible for consumers to take and develop their own pictures. (Fritz Goro/The LIFE Picture Collection/Getty Images)

glasses, and tinted windows. He applied for his first patent for polarizing sheets in 1929, and in 1932, he, along with Harvard colleague George W. Wheelwright, established Land-Wheelwright Laboratories in Cambridge, Massachusetts, to produce applications using this polarizing technology. In 1937, the company became known as the Polaroid Corporation.

During World War II, Land's company worked extensively with the U.S. military, producing optical equipment such as cameras, viewfinders, antiglare goggles, and gun sights. A previous invention, the Vectograph, assisted the war effort by giving a three-dimensional perspective of battlegrounds and aerial maps, enabling the military to perceive camouflaged enemy positions.

Land's most famous invention, the Polaroid camera, was prompted by his three-year-old daughter's dismay that photographs taken with conventional cameras could not be viewed immediately. He began the development process in 1943 and was ready to demonstrate his revolutionary instant photography

technology in 1947. When the first Polaroid cameras went on sale in 1948, all were sold within the first day. These first Polaroid images were sepia toned, and in 1950, the company achieved black-and-white capabilities. By 1963, Land had developed an instant color camera, and in 1972, he developed the iconic SX-70, the first truly one-step instant camera. (Previous versions had required steps such as treating the image with a coating.) It is estimated that during this era, more than half of U.S. households owned Polaroid cameras. In 1978, Land developed an instant color movie-making system, but it was not a commercially successful product.

During the Cold War era, Land served as science advisor to the federal government, assisting in the development of cameras for the U-2 spy plane and the Corona satellites. After his retirement in 1982, Land continued his scientific research, creating and financing the Rowland Institute for Science in Cambridge, Massachusetts. During this time, he developed laser technology capable of manipulating microscopic organisms such as bacteria, and he proposed the retinex theory of color vision perception.

Ansel Adams, a celebrated American landscape photographer, called Polaroid film “superior” and served as a prominent collaborator in the development of Polaroid films. Steve Jobs, cofounder of Apple Inc., credited Land with being a significant influence on his approach to invention and design. Land was awarded the Medals of Freedom (1963), Science (1967), and Technology (1988). During his lifetime, Land was granted 535 patents, second only to Thomas Edison.

Terry Steagall

See also Polaroids; *Vol. 2, Sec. 1: Camera*; Eastman Kodak Company; Edison, Thomas; Photographic Film; *Vol. 3, Sec. 2: Jobs, Steve*

Further Reading

American Chemical Society National Historic Chemical Landmarks. 2015. *Edwin Land and Polaroid Photography*. ACS.org.

McElheny, Victor K. 1999. *Insisting On the Impossible: The Life of Edwin Land*. Cambridge, MA: Perseus Books.

Lasers

“Light amplification by stimulated emission of radiation,” more commonly known as “laser,” has created revolutionary changes in American life in fields from science to medicine to the environment, and to technical and operational fields. Lasers have changed how we watch a movie, save lives, and expand our knowledge about our world and new worlds. Theodore H. Maiman, working for Hughes Research Laboratories, invented the laser in 1960, in concert with Charles H. Townes and Arthur L. Schawlow.

Laser light is created when electrons are excited by an electrical current. They move to a higher-energy state in atoms, and when they return to their normal state, they emit particles of light called “photons.” Lasers are devices that transmit intense light in nice, parallel wavelengths. Although the light from different lasers can be different colors, the light emitted from each laser is monochromatic, which means each is only one color. Also, unlike natural light, which tends to disperse, lasers light travels in the same direction and concentrates its intense light in only one spot at longer distances than natural light. Lasers are made from different materials, like gas, glass, polymers, and crystals.

In 1917 Albert Einstein (1879–1955) first proposed the stimulated emissions theory, which was about how atoms can go back to a state of equilibrium after being stimulated. Charles Towne developed a microwave amplifier that functioned with the same principles as a laser. This “maser” could not sustain continuous light output at first. Scientists, including Neils Bohr, argued that Towne’s maser could not exist because it violated Heisenberg’s uncertainty principle. Nonetheless, in 1964, Townes shared the Nobel Prize in Physics for his work on masers.

In 1960, Theodore Maiman was the first physicist to construct a laser with a cylinder of synthetic ruby. He created it at the Hughes Research Laboratory, and his work was based on the theories of Einstein, Charles Townes, and Arthur Schawlow. That same year, the first beam light laser was also created, reaching the distance of 1.15 μm .

In 1961, the laser made its first appearance on television in an advertisement. In October of that year, the

first neodymium glass laser was created, which was a better-resolution laser. It had higher uniformity and concentration than common lasers at that time. Later, a revolutionary event changed everything in the medical field. In December 1961, the first medical treatment with lasers on a human being was performed. This led to discoveries that not only helped people to heal but also enhanced human beauty. However, it was not until 1963 that the first cardiovascular surgery was performed by using a ruby laser. The surgery was done by a Dr. McGuff relating to the ablation of atherosclerotic plaques.

In 1962, the gallium arsenide laser, a semiconductor device was created. This device converted electrical energy into infrared light. However, the most commonly used laser today in homes and industry are diode lasers or LDs, which are semiconductor lasers. In 1978, the laser made the world of CDs and DVDs possible. In 2009, NASA sent the first lunar-orbiting laser to scout safe landing sites, measure lunar radiation, and identify potential moon resources.

New types of lasers are built everyday with new purposes and new potentials. Lasers have redefined our way of life, even modifying how we look with little effort. They save lives, making surgeries easier than before and less time-consuming.

Today, lasers are essential tools in the transformation of materials, like cutting or welding them, or in the production of new objects. They are also very useful in communication and the reading of information, as in supermarket scanners, TV and car remotes, or CDs, DVDs, and Blu-ray players. Lasers are also used by dermatologists and in other medical fields for human enhancement surgery—to correct vision, save lives, heal, and get rid of unwanted traits.

Lasers have also been used by NASA to create two-way communication. It aims to replace radio waves with what is known as “optical payload for laser comm science,” or OPALS. NASA has already sent information from the moon base to Earth with LLCD, which stands for “Lunar Laser Communication Demonstration,” but it was only one-way information. If OPALS becomes possible, two-way communication will increase resolution, and one day, we will be able to transmit three-dimensional videos via laser.

Jazmin Sandoval Castillo

See also National Aeronautics and Space Administration (NASA); *Vol. 3, Sec. 2*: CD and DVD; CD-ROM; Laser Cataract Surgery Device

Further Reading

- Riegel, Ronald J. 2017. *Laser Therapy in Veterinary Medicine: Photobiomodulation*. New York: John Wiley & Sons.
- Slegman, Anthony E. 1986. *Lasers*. Palo Alto, CA: Miller Scheier Associates.
- Taylor, Nick. 2000. *Laser: The Inventor, The Nobel Laureate, and The Thirty-Year Patent War*. New York: Simon & Schuster.

LED Lights

A light-emitting diode (LED) is a two-lead semiconductor that operates as a light source. It is commonly designed using a p-n junction diode that emits light when connected with an energy source. When a voltage is applied to the leads, electrons combine with electron holes in the device, releasing photons as energy. This process is called “electroluminescence,” where the color of the light is effected by the energy band gap of the semiconductor that it has been powered by. LED lights are small most of the time, usually below 1 square millimeter, and they are widely used as integrated optical components in electronic devices.

LED lightbulbs have gained considerable consumer popularity in the 21st century, although they are more expensive than traditional lightbulbs. They last longer and are significantly more energy efficient.

Xuanlin Xu

See also *Vol. 1, Sec. 1*: Street Lighting; *Vol. 3, Sec. 2*: Solar Energy

Further Reading

- Kim, J., Yoshihisa Yamamoto, and S. Somani. 2001. *Nonclassical Light from Semiconductor Lasers and LEDs*. Berlin; New York: Springer.
- Lenk, Ron, and Carol Lenk. 2011. *Practical Lighting Design with LEDs*. Piscataway, NJ: IEEE Press.

Liquefied Natural Gas (LNG) Carrier

A liquefied natural gas (LNG) carrier is a type of ship used to transport natural gas in large quantities where pipelines are impracticable. The first ocean LNG carrier was the *Methane Pioneer*, first built by the United States in 1958. It shipped off from the Louisiana Gulf to Canvey Island in the United Kingdom. Since then, LNG carriers have improved their capacity and capabilities, including more efficient regasification processes. The natural gas cargo is cooled down to -160°C at atmospheric pressure, where it significantly reduces the volume used by 600:1, making large quantities of natural gas efficient to transport.

LNG carriers are a valuable transportation tool. Since an increase in emerging markets in developing countries leads to a higher demand for energy, LNG carriers offer a simple and fast solution to the immediate need for fuel. These carriers are used to transport natural gas to supply poor areas, allowing such nations a stable source of fuel throughout the year. This transportation method makes resources from remote and deep ocean areas accessible to people around the world where pipelines cannot reach or cannot be placed fast enough.

The tanks are initially gas free because the cargo cannot be loaded with oxygen present, since the two elements would react and explode. An inert gas plant burns diesel in the air to produce a mix of oxygen, carbon dioxide, and nitrogen. This gas mix is blown into the tanks until oxygen levels are below 4 percent. Impurities in natural gas like sulfur and carbon dioxide are removed prior to loading it. The next step is to gas up and cool down the cargo; the tank is warmed to 68°C, and inert gas is blown in to remove any carbon dioxide present until it reaches 5 percent of volume. The tank is next filled with methane, and the gas is placed in a cargo containment system that cools the gas to -160°C, when it is placed in a high-pressure tank. Once cooled, it remains at atmospheric pressure with no significant changes. The LNG does have some drawbacks, since its cargo can evaporate away, losing 0.10 to 0.15 percent of volume per day. This is known as boil-off gas.

The United States is an energy-rich nation with vast natural gas reserves, so these carriers offer a way for it to expand its exports. With a higher demand, the

vessels are being redesigned to incorporate increased cargo capacity, more efficient systems, insulation, and liquefaction and regasification systems. In 2017, Russia created the world's first icebreaking LNG carrier capable of going through ice that is 2.1 meters thick, allowing more resources in the Arctic Circle to be accessible. Now, natural gas in the Arctic can be accessible year-round.

Andres Lopez

See also *Vol. 2, Sec. 3: Liberty Ships*

Further Reading

Seung Jae, Lee. 2008. *The Effects of LNG-Sloshing on the Global Responses of LNG-Carriers*. College Station: Texas A & M University.

Liskov, Barbara (1939–)

Barbara Liskov is recognized for being one of the first women to be granted a doctorate in computer science in the United States. In 2008, she won a Turing award for developing the Liskov Substitution Principle. Her contributions to programming language design and software methodology led to the development of object-oriented programming, a language structure that is used by virtually every coding platform today.

Barbara Jane Huberman was born on November 7, 1939, in Los Angeles, California, and was the eldest of Jane Dickhoff and Moses Huberman's four children. In 1970, she married Nathan Liskov, and by 1975 had had her first son, Moses Liskov. She earned her bachelor's degree in mathematics from the University of California, Berkeley in 1961. Liskov then worked as a programmer with the MITRE Corporation for about a year but left to work at Harvard University on language translation. In 1963, she returned to California to work with John McCarthy on some of his artificial intelligence projects at Stanford University. In 1965, Liskov earned a master's degree and then a doctorate in 1968 from Stanford, becoming the first woman in the United States to have a doctoral degree in computer science.

After receiving her doctorate, she returned to the Boston area to continue working at MITRE on

computer design and operating systems. It was there that she created the Venus computer, which used an operating system that was tailored for the creation of complex software. Liskov then returned to MIT that same year and joined the faculty as a professor in the Laboratory for Computer Science. While at MIT, she led a group that created the Argus language and developed the Liskov Substitution Principle.

In 2004, Barbara Liskov was awarded the John von Neumann Medal for her “fundamental contributions to programming methodology, and distributed systems.” In 2005, she was awarded an ETH Honorary Doctorate from the Swiss Federal Institute of Technology in Zurich, and in 2008, she received the 2008 Turing Award from the Association of Computing Machinery for her contributions to the design of programming languages and software methodology that led to the development of object-oriented programming. Liskov leads the Programming Methodology Group at MIT with a current focus on Byzantine fault tolerance and distributed computing. In 2012, she was inducted into the National Inventors Hall of Fame.

Liskov is currently an institute professor, the highest honor awarded to an MIT faculty member, and is Ford Professor of Engineering in the School of Engineering’s electrical engineering and computer science department.

Ryan M. Melendez

See also Fortran; Integrated Circuit; Johnson, Katherine Goble; Ochoa, Ellen; Single-Chip Microprocessor; *Vol. 3, Sec. 2: Computer/Information Technology*; Microchip; Perlman, Radia; Personal Computer (PC); *Vol. 3, Sec. 3: Hypertext*

Further Reading

Daylight, Edgar G. 2012. *The Dawn of Software Engineering: From Turing to Dijkstra*. Geel, Belgium: Lonely Scholar.

M16 Rifle

The M16 has been called one of the technological success stories of the 20th century. A lightweight, select-fire weapon with a high-capacity magazine, the M16

seemed to be the answer to combating America’s Cold War enemies. But before and even after it went into use in the mid-1960s, its principal adversaries were its patrons and its users.

Actually, the M16 was the army’s name for the AR-15, a high-velocity, semiautomatic or fully automatic rifle built by the Armalite Corporation in the 1960s. It wasn’t the army’s first choice. It had been on the hunt for a new infantry weapon since the end of World War II. Engagements with fanatical enemies had convinced it that a weapon firing a cartridge with more stopping power had to be developed. That led to the adoption of the M14, but while it certainly had the stopping power, thanks to a 7.62 mm slug, it was heavy and its recoil made the weapon inaccurate. It also didn’t feature a large-capacity magazine to keep the M14 in action. So, the search went on for something new and different.

Eugene Stoner, an Armalite engineer, had just that in mind when he developed the AR-15. It was different in every way. For starters, it wasn’t built like most weapons, which involved the machining and casting of metal parts. The AR-15’s pieces were stamped, pressed and forged, and equipped with a plastic stock in place of the traditional wooden one. The inside of the AR-15 was just as innovative. The piston assembly used to make the weapon work was gone; in its place was a simple tube that fed gas into the bolt carrier, which propelled shells out of the barrel. And coming out of that barrel was a 5.56 mm slug fed from a high-capacity magazine. Smaller than the 7.62 mm round and less lethal than the .30-caliber slug, the AR-15’s ammo proved it could meet the army’s expectations. It could penetrate a U.S. Army helmet at 500 yards, retain a velocity in excess of the speed of sound, and match or exceed the wounding ability of the .30-caliber cartridge. In addition, the AR-15 weighed less than seven pounds, which in the view of the U.S. Army’s Infantry Board made it an ideal weapon for the fully loaded, and sometimes overloaded, GI to carry.

While the Infantry Board was willing to sign off on the AR-15 and rechristen it the M16, the Ordnance Board, another department within the army, didn’t think the weapon was accurate enough. It produced studies that showed that once fired, the small 5.56 mm shell immediately began to lose speed and stopping power, and its trajectory could be easily diverted by

leaves or even sticks on the way to a target. Since the number of hits was more important to the Ordnance Board than the number of shots fired, it came out against the M16. Further complicating matters was the fact that American forces, along with troops belonging to the North Atlantic Treaty Organization (NATO), had sought to standardize weapons and equipment and had earlier settled on the 7.62 mm round. Any deviation from that policy could cause severe disruptions within the alliance. Accuracy and continuity carried the day, and the army rejected the M16.

The debate over the use of the M16 continued until 1967, when the controversy landed on the desk of Defense Secretary Robert McNamara. Other service branches had adopted the weapon, including the army's own Special Forces, for use in Vietnam. That unit concluded that the M16 was superior for the type of operations it was conducting. Success in jungle warfare depended less on accuracy and more on firepower. The M16 was easy to carry and just as easy to bring into action. Plus, with its high-capacity magazine and full-auto feature, a soldier could spray a target, reasonably sure he had hit it, and be confident he would live to talk about it. But that's not to say the M16 didn't still have problems. The gas-operated, pistonless system that made the M16 so light occasionally caused the weapon to jam during use. Jamming also occurred when users taped clips of bullets together to allow for a more rapid rate of fire. Sometimes one of the clips got hung up in the feed mechanism and caused a malfunction.

With the Special Forces data in hand, and taking the operational liabilities into consideration, McNamara ordered the M16's purchase by the U.S. Army. It was bad news for NATO, as its 7.62 mm cartridge wouldn't fit into a weapon destined to become the most widely used in the world. It was also bad news for Eugene Stoner and the Armalite Corporation, as the contract to mass-produce the M16 was awarded to Colt Industries.

John A. Morello

See also Military-Industrial Complex; *Vol. 1, Sec. 1: Kentucky Long Rifle*

Further Reading

Olson, James. 1987. *Dictionary of the Vietnam War*. New York: Bedrick Books.

Magnetic Resonance Imaging (MRI)

Magnetic resonance imaging (MRI) is a technique used for medical purposes to form images of the body. It uses magnetic fields and pulses of microwave energy to create images of the organs of the patient. The first MRI was created in 1970 by Raymond Damadian, who discovered that each organ emits a different resonance wave due to a difference in water content. This was the foundation for the MRI to be able to image individual tissues and organs. It has been in use in hospitals since 1980.

This method gives medical personnel additional information about the patient, such as the movement and presence of disease, not just the structural image provided by an x-ray. It is a landmark medical technique since it is a noninvasive procedure used to diagnose diseases. In some cases, an MRI can be used to detect cancer since cancer cells emit a different hydrogen NMR signal than healthy cells because cancer cells contain more water. MRIs are used to find various problems such as tumors, internal bleeding, and multiple sclerosis.

The medical uses of MRIs are wide due to the composition of the human body being two-thirds water, which contains hydrogen atoms. When the human body is exposed to a strong magnetic field, the nuclei of the hydrogen atoms orient themselves in a certain direction. Pulses of radio waves are then emitted at the body, causing the hydrogen to emit a resonance wave. This wave causes a difference in the oscillation of the nuclei, which is detected and processed to create the image of an organ.

Since its original use in full-body scans, more specialized applications of MRIs have been invented, such as diffusion MRI and magnetic resonance angiography (MRA). Diffusion MRI measures the diffusion or random motion of water within tissue. This gives a better understanding of the structure of organs, since it often reflects interaction with many neighboring areas. It is used for neuroimaging and is commonly used to determine if a patient has had an acute stroke or a neurological disorder. MRA focuses on imaging blood vessels, generating images of arteries to analyze them for any present disease or blood flow issues. This technique is most commonly used to image blood vessels in the legs, kidneys, and brain. The image

generated provides information on the blood flow and the current state of the blood vessel walls. It offers an alternative to traditional angiography, which involves inserting a catheter into the body. MRA is an alternative, noninvasive procedure.

Andres Lopez

See also Vol. 3, Sec. 2: Artificial Heart; Insulin Pump; Vol. 3, Sec. 3: Cancer Research; Human Genome Project

Further Reading

Kuperman, Vadim. 2000. *Magnetic Resonance Imaging: Physical Principles and Applications*. San Diego: Academic Press.

Vlaardingerbroek, Marinus T., and Jacques A. den Boer. 2004. *Magnetic Resonance Imaging: Theory and Practice*. Berlin: Springer.

MASER

A MASER, or “microwave amplification by stimulated emission of radiation,” is a device that emits a self-sustaining stream of microwave radiation by directing microwaves through free electrons. The original MASERS were invented to study the structure of molecules, atoms, and atomic nuclei. After World War II, attempts were made to reconfigure radar devices to study the smallest building blocks of matter, but no one was able to produce electromagnetic radiation less than one centimeter in wavelength. The breakthrough occurred when pioneering physicist Charles H. Townes configured an apparatus that utilized microwave radiation to excite molecules of ammonia gas in a resonant cavity, which then chain reacted as the excited molecules emitted radiation—which then further promoted radiation emission. The feedback between the excited molecules and the microwaves exciting them created a steady, self-sustaining stream of amplified microwaves. The original device’s total power was around 10 nanowatts and over one centimeter in wavelength, but the energy emission was uniform in wavelength, which had never been accomplished before.

The MASER’s inventor, Charles H. Townes, was born July 28, 1915, in Greenville, South Carolina. He

received his PhD in physics at the California Institute of Technology, and then he worked on the technical staff of Bell Telephone Laboratories, designing radar systems during and after World War II. His first functioning MASER was tested successfully in 1954 while he worked at Bell Labs, but skepticism persisted that there were any practical applications for the device. Four years later, he and Arthur Schawlow, Townes’s fellow physicist and brother-in-law, demonstrated how the principle of the MASER could be applied to both infrared and optical electromagnetic frequencies. Their proposal for a LASER (“light amplification by stimulated emission of radiation”) was patented in 1960, and in 1964, he received the Nobel Prize in Physics for his work relating to optical physics and quantum electrodynamics, which he shared with Nikolay Basov and Aleksander Prokhorov. Townes and his assistants were also the first to detect complex molecules in space and to provide the first measurements of the Galactic Center. Townes died on January 7, 2015 at age 99.

Arthur L. Schawlow, a pioneer in MASER technology alongside Townes, was born on May 5, 1921, in Mount Vernon, New York. He received his graduate degree at the University of Toronto and then studied under Townes—considered a leader in the field of microwave spectroscopy—at Columbia University. While there, he married Townes’s younger sister, Aurelia, transferring to Bell Labs to study superconductivity to avoid Columbia’s antinepotism policies. The year after he and Townes patented the LASER, he joined Stanford’s Physics Department. He was still associated with Stanford when he shared the 1981 Nobel Prize in Physics with Nicolaas Bloembergen and Kai M. Siegbahn for “their contribution to the development of laser spectroscopy.” Schawlow died on April 28, 1999, in Palo Alto, California.

Andres Elvira

See also Vol. 2, Sec. 2: Bell Telephone Laboratories; Vol. 2, Sec. 3: Radar

Further Reading

Gray, Malcolm. 2012. *Maser Sources in Astrophysics*. Cambridge: Cambridge University Press.

Townes, Charles H. 1999. *How the Laser Happened: Adventures of a Scientist*. New York: Oxford University Press.

McClintock, Barbara (1902–1992)

Cytogeneticist Barbara McClintock was the first woman to win an unshared Nobel Prize. By studying heredity and, more specifically, genes, she proved that genetic elements can sometimes change position on a chromosome and that this causes nearby genes to become active or inactive.

Barbara McClintock was born on June 16, 1902, in Hartford, Connecticut, to Sara Handy McClintock and Thomas Henry McClintock. Her parents first named her Eleanor but changed her name to Barbara after deciding that Eleanor was too delicate a name for their sturdy daughter. McClintock's father was a family doctor, the child of immigrants from Britain, and her mother was from an upper-class family from Boston, with a career in poetry and art. Barbara McClintock had two older sisters, Marjorie and Mignon, and a younger brother, Malcolm.

In 1908, the McClintock family moved to Brooklyn, where McClintock graduated high school in 1919. While in high school, McClintock discovered her love of science. McClintock's mother did not want her daughter to attend college, because she believed it would make her daughter unmarriedable. Luckily, McClintock's father intervened. In 1919, she began classes at Cornell.

Barbara McClintock took her first course in genetics in 1921, the only course in genetics open to undergraduate students at the time. Naturally gifted in the subject, she caught the attention of Claude B. Hutchison, professor in the Department of Plant Breeding, College of Agriculture, who promptly recommended that she attend a graduate-level course as soon as possible—the only other genetics course given at the university.

In the 1920s, genetics was not a generally accepted discipline. Only a couple of decades had passed between then and the rediscovery of Mendel's principles of heredity. Regardless, McClintock devoted her studies to genetics, specifically plant genetics. After graduating with a bachelor of science degree in 1923, she earned a master's and then in 1927 a PhD in botany, all from Cornell University.

McClintock won a Guggenheim scholarship that allowed her to study in Germany in 1933 and 1934. She had planned to work with prominent geneticist

Curt Stern, but when he fled Nazi Germany for the United States, she studied with Richard Goldschmidt. Rising anti-Semitism and war sentiment in Germany made McClintock uneasy, so she returned to the United States. Cornell next offered McClintock a position as instructor in the Botany Department. Along with teaching, she also researched plant genetics. While at Cornell, she won a two-year Rockefeller Foundation grant.

In 1941, McClintock became an assistant professor at the University of Missouri and, in the same year, a visiting professor at Columbia University. In 1944, McClintock began studying the relationship between patterns on corn plants and their chromosomes, focusing primarily on purple-spotted corn.

During the 1940s and 1950s, McClintock discovered that genes are responsible for determining physical characteristics, and she proved that they used transposition to change characteristics from one generation to another. The next year, she presented her work at Cold Spring Harbor's annual summer symposium. One colleague said that she had done more to uncover the genetic structure of a particular mold fungus than all the scientists that had studied the organism before. In 1944, she returned to her study of maize genetics. Her findings in gene transposition in the 1940s and 1950s fundamentally changed the study of genetics and chromosome mechanisms. As her work continued to break ground, some scientists took issue with her findings. In 1953, she took a hiatus from publishing, hoping that other geneticists would eventually catch up to her work.

In 1957, McClintock won yet another grant, this one from the National Science Foundation, to study indigenous maize in South America. McClintock relished the opportunity to undertake a study in evolutionary biology that would fundamentally change paleobotanists' understanding of plant evolution.

McClintock did not go without recognition. In 1983, she became the first woman to receive an unshared Nobel Prize in Physiology or Medicine. She was 81 years old. She was also awarded membership in the National Academy of Sciences, gaining the presidency of the Genetics Society for a time, the National Medal of Science from President Richard Nixon, the very first MacArthur Laureate Award, and more.



Geneticist Barbara McClintock won the 1983 Nobel Prize in Medicine for her work on genetic recombination by crossing over. Scientists recognize her as one of America's most significant scientists. (Barbara McClintock Papers, American Philosophical Society)

She died on September 2, 1992, at the age of 90 from natural causes at Huntington Hospital in Huntington, New York. Dr. Barbara McClintock died peacefully, her mind remaining sharp and methodical in her research until her time of death.

Though her work was largely forgotten for decades, interest in women in science in the late 20th and early 21st centuries led to McClintock's rediscovery. Biographies about McClintock make it clear that much of the difficulty she encountered in her life as a scientist had stemmed from the fact that she was a woman. In 2005, the U.S. Post Office issued a Barbara McClintock stamp.

Peg A. Lamphier

See also Goeppert-Mayer, Maria; Hopper, Grace; Jackson, Mary Winston; National Science Foundation (NSF); Rocket Girls of JPL; Taussig, Helen; *Vol. 2, Sec. 1*: Harvard Computers; *Vol. 3, Sec. 2*: Genetic Engineering

Further Reading

Comfort, Nathaniel C. 2001. *The Tangled Field: Barbara McClintock's Search for the Patterns of Genetic Control*. Cambridge, MA: Harvard University Press.

Fox Keller, Evelyn. 1984. *A Feeling for the Organism: The Life and Work of Barbara McClintock*. New York: W. H. Freeman & Co.

Mercury 13

The “Mercury 13” is a nickname for the group of women who successfully completed the first phase of NASA’s physical and psychological testing to qualify as astronauts. Most of these women were accomplished pilots aspiring to be the first female astronauts. In 1960, Geraldyn “Jerrie” Cobb was the first to pass all three phases of the test. Altogether, 20 women were invited to complete the first phase of astronaut testing, and 13 passed. They became known as the “First Lady Astronaut Trainees” or FLAT, and later in 1995, the term “Mercury 13” for them was coined by Hollywood producer James Cross.

The women in the Mercury 13, or FLAT, were: Jerrie Cobb, Wally Funk, Irene Leverton, Myrtle “K” Cagle, Janey Hart, Gene Nora Stumbough (Jessen), Jerri Sloan (Truhill), Rhea Hurrle (Woltman), Sarah Gorelick (Ratley), Bernice “B” Trimble Steadman, Jan Dietrich, Marion Dietrich, and Jean Hixson.

The tests administered to these women were privately funded as part of Project Mercury and not officially through NASA. Project Mercury was started by William Randolph Lovelace II, chairman of the NASA Special Advisory Committee on Life Science. Lovelace was influential in creating the tests undergone by male NASA astronaut candidates and was curious about how women would perform on the tests.

Phases II and III of this testing were never administered to the women. The military halted the use of their equipment until Lovelace had an official order from NASA to continue testing. Since Project Mercury was privately funded and not an official project of NASA, Lovelace was not able to gain NASA’s approval, so the Mercury 13 were unable to continue testing. These women were not part of NASA’s astronaut program and never flew in space, even though they did the same tests as the male astronauts. The male astronauts later became known as the “Mercury 7.” The Mercury 7 included: Alan Shepard, Gus Grissom, John Glenn, Scott Carpenter, Wally Schirra, Gordon Cooper, and Deke Slayton.

The women of the Mercury 13 never officially became NASA astronauts, but they were accomplished, attained honors, and had overall successful

lives. The initial woman to undergo these tests, Jerrie Cobb, was inducted into the National Aviation Hall of Fame on October 6, 2012. As a group, Jerrie Cobb, Jerri Truhill, “B” Steadman, Rhea Woltman, Sarah Ratley, Gene Nora Jesson, Irene Leverton, and Myrtle “K” Cagle were awarded with honorary doctor of science degrees from the University of Wisconsin-Oshkosh on May 12, 2007.

Chelsea Kirkpatrick

See also National Aeronautics and Space Administration (NASA); *Vol. 3, Sec. 2: Ride, Sally*

Further Reading

Ackmann, Martha. 2004. *The Mercury 13: The True Story of Thirteen Women and the Dream of Space Flight*. Reprint ed. New York: Random House.

Cobb, Jerrie, and Jane Rieker. 2012. *Woman into Space: The Jerrie Cobb Story*. n.p.: Literary Licensing.

Sherr, Lynn. 2014. *Sally Ride: America’s First Woman in Space*. 2nd ed. New York: Simon & Schuster.

Military-Industrial Complex

The phrase “military-industrial complex” (MIC), which refers to close ties between the American military leadership and the American defense industry, was first coined by President Dwight D. Eisenhower in his televised farewell address in 1961. Although the American military and businesses had cooperated during previous wars, Eisenhower believed that Cold War (1945–1989) fears would lead to the MIC’s “unwarranted influence.” He warned, “The potential for the disastrous rise of misplaced power exists and will persist.” Therefore, he asked Americans to be vigilant, and he proposed two solutions for the problem. First, he recommended scaling back the size of the military during times of peace. Second, he believed that an investment in new weapon technologies would give the United States an edge over other nations.

Throughout the 1960s and 1970s, critics of the Vietnam conflict (1955–1975) routinely referred to the MIC as a root cause of American involvement. And, as the war dragged on year after year, Eisenhower’s

warning seemed prophetic. By the 1980s, references to the MIC declined even though the U.S. defense budget skyrocketed during President Ronald Reagan's administration (1981–1989). After the Cold War, presidents found it difficult to secure popular support for maintaining a wartime-size military during peacetime.

Eisenhower, a former general who commanded the troops during the D-Day invasion that had liberated France from the Germans (1944), was not soft on the issue of defense. He believed that a strong military was important. However, he objected to wasteful military spending due to military contractors who padded bills. Eisenhower was not the only leader with this concern. Eight years before his speech, the U.S. Congress launched an investigation of deals made by military leaders and contractors. According to the report, \$1 million had been spent on “unnecessary” chain-link fences for the Air Force, \$3 million on “useless” navy forklifts, and \$45 million on “unsuitable” army overcoats. Led by Representative R. Walter Riehlman (a New York Republican), Congress deemed the spending “costly and wasteful.” In spite of the report, government defense spending continued to rise unabated. By the time of Eisenhower's speech, defense spending stood at \$46.4 billion (a 38 percent increase since 1949).

Certainly, the phenomenon of cooperation between the military and civilian businesses was not new. In the 1880s, the United States set about building a new navy. The massive undertaking required cooperation between political leaders, naval officers, and industrialists. The huge sums of money exchanged between the government and private businesses funded the creation of the “Great White Fleet,” which Theodore Roosevelt proudly showed off to the world (in a world tour) during his presidency.

During World War I (1914–1918), the War Industries Board (WIB), a group of military leaders and private industrialists, coordinated to supply American troops. At the direction of the WIB, factories went from producing consumer goods (including automobiles, home radios, and home appliances) to producing military materials (including airplanes, military radios, and rifles). During World War II (1939–1945), the War Production Board (WPD) had a similar makeup and function as the WIB. However, the WPD managed a

much larger operation, because World War II was the largest war to date.

Throughout American history, the United States had followed the same cycle of mobilization (with a large military budget) during war and demobilization (with a reduced military budget) during peacetime. Initially, the country followed the same pattern at the conclusion of World War II. However, the deterioration of U.S.–Soviet relations after World War II resulted in the two nations becoming enemies. In 1949, four years after the war, the Soviets tested their first atomic bomb. The worsening relations and the fact that the Soviets were perceived as a threat reversed American demobilization.

President Harry S Truman (1945–1953) pushed for the creation of the first hydrogen bomb, which was much more powerful than the atomic bombs that the United States had dropped on Japan during World War II. Looking for an alternative to nuclear warfare, Americans and Soviets entered into an arms race as they built up their storehouses of conventional weapons. An important feature of the Cold War tied to the use of conventional weapons was the policy of containment. Just like dominoes in a row, Eisenhower and others argued that if one nation fell to communism, bordering nations would also fall. Beginning with Truman, all Cold War-era U.S. presidents practiced their own particular policies of containment. For example, the United States (with help from the United Nations) prevented the spread of communist ideology during the Korean conflict (1950–1953) and Vietnam conflict (1955–1975).

By 1957, the Cold War included both an arms race and a space race. That year, the Soviets launched Sputnik I, the first man-made object to orbit the earth. Americans reacted in several ways to the Soviet display of its new technology. Politicians blamed American technological inferiority on a failure of the American educational system. In 1958, Congress passed the National Defense Act, which provided millions of dollars to public schools for their science and foreign language programs.

That same year, Congress budgeted for the establishment of the National Aeronautics and Space Administration (NASA) to help the United States catch up and win the Space Race. Some military leaders voiced concern over what they called the “missile gap.” In other words, Sputnik technology had made it possible for

Soviets to place a nuclear warhead on a missile that could then orbit the earth and destroy targets from vast distances. The Soviet technology left the United States at a tremendous disadvantage in 1957. Some Americans reacted to Cold War fears by building bomb shelters in their backyards. Schools held atomic bomb drills in which they had children hide under tables and desks in preparation for a possible Soviet attack. These Cold War fears and attitudes threatened to expand the American military beyond any previous peacetime limits.

By the 1950s, several major U.S. corporations were entirely dependent on military contracts. In addition, U.S. corporations became one of the world's leading exporters of conventional weapons. In fact, the huge profits from arms sales were a major factor in American economic growth. Eisenhower pointed out that when military and political leaders were corporate stockholders (who stood to benefit from profits), their endorsement of certain military decisions should be scrutinized to ensure that greed and the desire for personal gain did not compromise national interests. During the Vietnam conflict, for example, more conventional bombs were dropped by the United States on North Vietnam than all of the conventional bombs dropped by all of the warring nations during World War II. Throughout the long Vietnam conflict, military suppliers made great profits.

Eisenhower proposed a solution to the threat of a ballooning military establishment. He recommended a reduction in troop numbers and an increased emphasis on development and dependence on sophisticated technologies. Surely, the development of incrementally more powerful bombs during the Cold War was an example of this kind of strategy. Perhaps the most striking example of a reliance on new military technologies was President Ronald Reagan's plan for the trillion-dollar Strategic Defense Initiative ("Star Wars"). The purpose of "Star Wars" technology was to deploy a satellite laser network over the earth to protect the United States against an incoming nuclear attack. Unfortunately, after spending \$70 billion on research and laboratory tests, scientists were unable to build a functional Star Wars network.

Reagan believed that the best way to defeat the Soviets was by outspending them. He increased defense spending to build more ships, tanks, airplanes, and nuclear weapons. He pushed for government grants for

research institutions working on advanced weaponry. In fact, defense spending ate up so much of the budget that it led to funding cuts in many social programs, including food stamps, Medicare, education, and Social Security. Occasional critics of the massive defense budget pointed to government records that documented highly overpriced military hammers and toilet seats. Some explained the high prices by accusing the MIC of abuses. Others speculated that secret projects might have been funded by the padded bills. In general, critics charged the Reagan administration with the development of expensive yet malfunctioning weapons and a tremendous waste of the budget.

After the Cold War, President Bill Clinton (1993–2001) greatly reduced the size of the military, and he continued to rely on innovations in technology to remain a military leader in the world. President George W. Bush (2001–2009) built a land-based missile defense system nicknamed "Son of Star Wars." The combined cost of both the failed Star Wars project and its land-based descendant was approximately \$100 billion.

Rolando Avila

See also Antiballistic Missiles (ABMs); National Aeronautics and Space Administration (NASA); *Vol. 2, Sec. 3: Atomic Bombs/Nuclear Weapons; Hydrogen Bomb; Vol. 3, Sec. 2: Strategic Defense Initiative (SDI)*

Further Reading

- Hartung, William D. 2001. "Eisenhower's Warning: The Military Industrial Complex Forty Years Later." *World Policy Journal* 18, no. 1: 1–7.
- Koistinen, Paul A. C. 1980. *The Military-Industrial Complex: A Historical Perspective*. New York: Praeger.
- Ledbetter, James. 2011. *Unwarranted Influence: Dwight D. Eisenhower and the Military-Industrial Complex*. New Haven, CT: Yale University Press.

Minsky, Marvin (1927–2016)

Marvin Minsky was an American scientist who was part of a group of scientists and mathematicians considered to be the founding fathers of artificial intelligence (AI). Minsky and his work in AI led him to cofound the Massachusetts Institute of Technology

Artificial Intelligence Laboratory now known as the Computer Science and Artificial Intelligence Laboratory. The lab was responsible for building and developing robots and creating revolutionary programs. Minsky also published several books on artificial intelligence as well as philosophical analyses. He is the recipient of the ACM A. M. Turing Award, which is thought of as the Nobel Prize of computing, along with several others over the years of his work.

Minsky was born in New York City in August 1927. For his early education, he attended the Ethical Culture Fieldston School, followed by the Bronx High School of Science, and finally Phillips Academy. Next, he was off serving in the U.S. Navy during World War II. In 1950, he earned his bachelor's degree in mathematics from Harvard University in Cambridge, Massachusetts. In 1954, he received his PhD from Princeton University, building the first randomly wired neural network learning machine.

After receiving his PhD, he was recommended as junior fellow at Harvard. In 1958, he began teaching at MIT, and Minsky, along with John McCarthy, founded the Artificial Intelligence Laboratory there, where it built pioneering robots. In the lab, they worked on ways to influence the human psychological process through AI and attempted to create machines to imitate human perception and intelligence. They also created practical robots. Minsky accurately predicted that microsurgery could be done by a surgeon at one end of a telepresence system with adjustable scale and focus, with a machine on the other end doing the hands-on, small-scale part of the skilled work.

In a foreshadowing of microsurgery, he created the first robot with mechanical hands and tactile sensors. Minsky also argued that space exploration and nuclear material processing would be simpler using machines driven locally by computers and remotely by humans.

In the 1960s, he worked with mathematician Seymour Papert to develop better neurally inspired mechanisms. They wrote *Perceptrons*, which analyzed artificial neural networks and their abilities. In the 1970s and 1980s, they developed theories of intelligence and radical approaches to children's education through an educational programming language called Logo.

During the mid-1970s, Minsky developed the theory of frames, a way of describing entities and situations using a template-like representation. In 1980 he

published *K-Lines: A Theory of Memory*, a journal article that described the group of “mental agents” that activate when a human solves a problem or has a new idea. These and many other ideas of his came together in Minsky's 1986 book *The Society of Mind*. He wrote that intelligence may come from behavioral factors that are undoubtedly nonintelligent. In 2006, he published *The Emotion Machine*, which elaborated on the ideas in *The Society of Mind* and reviewed scientific progress on artificial intelligence.

Minsky earned many awards, including the fourth-ever ACM A. M. Turing Award in 1969 for his role in AI. In 1990, he received the Japan Prize, followed by the International Joint Conference on Artificial Intelligence Award for Research Excellence in 1991. In 2001, he was awarded the Benjamin Franklin Medal. In 2006, he earned a place in the Computer History Museum and in 2011 in *Intelligent Systems* magazine's AI's Hall of Fame. Finally, in 2014, he won the Dan David Prize for the field of Artificial Intelligence, the Digital Mind. His last position was Toshiba Professor of Media Arts and Sciences and professor of electrical engineering and computer sciences at the Computer Science and Artificial Intelligence Laboratory. The founding father of AI passed away at the age of 88 on January 24, 2016.

Madison Pena

See also Vol. 3, Sec. 2: Artificial Intelligence (AI)

Further Reading

Haugeland, John. 1997. *Mind Design II: Philosophy, Psychology, and Artificial Intelligence*. A Bradford Book. Cambridge, MA: MIT.

Minsky, Marvin. 1988. *The Society of Mind*. New York: Simon & Schuster.

Rifkin, Glen. 2016. “Marvin Minsky, Pioneer in Artificial Intelligence, Dies at 88.” *New York Times*. January 25.

Moog, Robert (1934–2005)

Robert Arthur “Bob” Moog was born May 23, 1934, in Queens, New York. He is the founder of Moog Music Inc. He is known as an engineer and the founding father of electronic music. He also invented the Moog synthesizer.

Moog attended the Bronx High School of Science in New York and graduated in 1952. He then attended Queens College and earned a bachelor's degree in physics. He later earned a bachelor's degree in electrical engineering from Columbia University. For his PhD in 1965, he studied engineering physics at Cornell University. When he was 20 years old, Moog and his father had begun to build theremins—electronic musical instruments controlled without physical contact. In them, two metal antennae produce a magnetic field, and one waves one's hands in the field to control the volume and the pitch. Inspired by his father, Moog fell in love with electronic music.

In 1961, Moog made a living selling theremin kits at \$50 apiece. Also in that year, he wrote an article about them for *Electronic World*, an electronics magazine, and he received about 4,000 orders for more theremins, which he built in this three-room apartment. About two years later, Moog was inspired by composer Herbert A. Deutsch, to construct the first Moog modular synthesizer composed of two voltage-controlled oscillators, two voltage-controlled amplifiers, and a controller that could turn the sounds on and off and change the pitch and rates of modulation.

The following year, Moog brought his hand-made Moog modular prototypes to the Audio Engineering Society convention to demonstrate it. He took orders for it there, and his business grew. In 1967, he incorporated R. A. Moog Company, now called R. A. Moog Inc., and began the introduction of Moog modular Synthesizers I, II, and III.

Moog himself did not play music, but in the following year, his company released Wendy Carlos's *Switched-On Bach* album, an entire album recorded with a custom-made Moog modular synthesizer. In 1970, Bill Waytena purchased the company and soon released different models of "Minimoog," and the company was relocated to Buffalo, New York, in 1971. In 1977, Moog left the company to serve as vice president of new product research at Kurzweil Music Systems, where he stayed until 1989. After that, he rediscovered his interest in theremins and designed the series 91 theremin in 1996.

During the 1970s, less expensive digital synthesizers came to the market. Moog's company did not have the right to produce this kind of synthesizer, and

that led his company to bankruptcy. He sold the rights to his company and in 1978 moved to Asheville, North Carolina, to set up the Big Briar music company, building theremins and analog synthesizers. In the meantime, the Moog synthesizer continued to gain popularity in the 1980s; most musicians preferred it for its "warmer" sound over that of less expensive brands.

In April 2005, Robert Moog was diagnosed with inoperable brain cancer. On August 21, 2005, he passed away at his home in Asheville. Afterward, the Bob Moog Foundation was created with the aim of continuing his work developing electronic music.

Rosanne Welch

See also Vol. 3, Sec. 3: MIDI (Musical Instrument Digital Interface)

Further Reading

"A Conversation with Bob Moog: Analog vs Digital Sound Generation." 2005. *Keyboard Magazine*. January. <https://www.moogmusic.com/legacy/conversation-bob-moog-analog-vs-digital-sound-generation>, accessed August 31, 2018.

"Robert Moog." 2010. *Bio.com*. March 9. <https://www.biography.com/people/robert-moog-21338711>, accessed August 31, 2018.

Morgan, Mary Sherman (1921–2004)

Mary Sherman Morgan was the first female rocket fuel scientist in the United States. She invented Hydyne liquid fuel, which powered the Jupiter-C rocket. Though in use only for a limited time, Hydyne fuel was responsible for launching the rockets that placed the United States' first satellite, Explorer I, into space.

Born on November 4, 1921, on a farm in North Dakota, Morgan graduated as valedictorian of her high school in 1939. She enrolled at North Dakota's Minot State University to study chemistry. While she was there, World War II broke out. She dropped out of college and went to work for the Plum Brook Ordnance Works munitions factory in Sandusky, Ohio, for which she needed top security clearance. She was part of the

team that manufactured explosives such as trinitrotoluene (TNT), dinitrotoluene (DNT), and pentolite.

After the war ended, Morgan took a job with North American Aviation's Rocketdyne Division in Canoga Park, California, and was soon promoted to theoretical performance specialist, calculating the expected performance of new rocket propellants. She was the only woman on a team of 900 engineers and one of only a few without a college degree.

North American Aviation was awarded a contract to develop more powerful fuel for the Jupiter missile program. Morgan worked with a group under the direction of Dr. Jacob Silverman at the Rocketdyne Division and was named technical lead on the contract. Her work resulted in a new propellant, Hydyne, which was used in the Redstone R&D flight in November of 1956. Hydyne was a blend of 60 percent unsymmetrical dimethylhydrazine (UDMH) and 40 percent diethylenetriamine (DETA), making it more powerful—and more toxic—than the previously used ethyl alcohol fuel. Hydyne subsequently powered three Jupiter-C nose cone test flights and was used in launching America's first satellite, Explorer I, into orbit in January 1958. The launch of Explorer I rescued America's tarnished reputation in the wake of Russia's launch of Sputnik 1 and 2.

Morgan married a coworker and had children, continuing to work for North American Aviation and becoming a champion bridge player. She died in 2004. Her contributions to the Jupiter missions went largely unknown, as she had shunned publicity during her life and because she was a woman. Her colleagues referred to her as "America's first female rocket scientist," an achievement that few knew about until her son published a book about her life.

Tiffany Rhoades

See also Brown, Marie Van Brittan; *Vol. 2, Sec. 1*: Roebling, Emily; *Vol. 2, Sec. 3*: Clarke, Edith; *Vol. 3, Sec. 2*: Perlman, Radia

Further Reading

Morgan, George D. 2013. *Rocket Girl: The Story of Mary Sherman Morgan, America's First Female Rocket Scientist*. New York: Prometheus Books.

Nanotechnology

Nanotechnology is engineering, science, and technology all combined at the nano scale to study and manipulate molecules and atoms. The prefix "nano" means "one-billionth"; therefore, one nanometer is one-billionth of a meter. Nanotechnology, although a new science today, has actually been used since the Middle Ages. Painters in the premodern era were simply not aware that they were using nanotechnology to design stained glass windows. They would trap nanoparticles of gold in a glass matrix, creating a bright red color in the glass. Scientists now know that, depending on which metal is used and the size of its nanoparticles, a variety of colors can be generated in such glass.

Physicist Richard P. Feynman first formally introduced nanotechnology into the modern era by in his classic talk on December 29, 1959, at the annual meeting of the American Physical Society at the California Institute of Technology. He said that physics could progress more than it had in his day by gathering enormous amounts of information and storing it in unimaginably small spaces, such as the way information is stored in DNA molecules, holding all of a person's genetic information. Nanotechnology is work done at the molecular level, building larger structures atom by atom to create a new organization of molecules. Nanotechnology can be used across all the sciences to help improve the world, from objects invisible to the naked eye to the grand creations that allow us to move from point A to point B or planet to planet.

In the world of medicine, scientists are developing nanoparticles that can help deliver drugs to treat disease or infection in the human body, including cancer. Nanotechnology can also help us create instruments for space exploration, reduce the weight of aircraft, and improve spacesuit performance. Bio-nano robots applied as an outer layer of a spacesuit could detect damage and alert the user.

Nanotechnology is even involved in the food industry. Nanosensors are detectors that can test for harmful bacteria more affordably than sending produce out to be tested in labs. This may reduce the likelihood of catching salmonella or other bacterial disease from food.

Everything on the planet is made up of atoms, from the cars we drive to the air we breathe. They are invisible to the naked eye and even some microscopes. The size of nanoparticles is around 1 to 100 nanometers, whereas a red blood cell is 5.5 nanometers. To see nanoparticles and nanomaterials, we use specific types of microscope such as the scanning tunneling microscope. We also must manipulate nanoparticles or nanomaterials precisely. Nano materials can be constructed into shapes like tubes, wires, shells, or cones.

Nanotechnology continue to shape the way humans live, from medical advancements to handle cancer to the possible conquest of Mars.

Emma E. L. Burke

See also *Vol. 3, Sec. 3*: Quantum Science

Further Reading

Drexler, K. Eric. 1992. *Nanosystems: Molecular Machinery, Manufacturing, and Computation*. New York: Wiley.

Feynman, P. Richard. 1960. "There's Plenty of Room at the Bottom." *Caltech Engineering and Science* 23, no. 5 (February): 22–36.

McCarthy, Wil. 2003. *Hacking Matter*. New York: Basic Books.

Rogers, Ben. 2007. *Nanotechnology: Understanding Small Systems*. Boca Raton, FL: CRC Press.

Napalm

Napalm is a jellied fuel, often gasoline, used as an antihuman military weapon. It was first successfully tested in 1942 at Harvard University. Designed to stick to human skin, napalm also deoxygenates the air when it burns, creating a toxic, carbon-dioxide-rich environment. The United States first used napalm in Japan during World War II and then in the Korean and Vietnam Wars.

Napalm is named for its two thickening and gelling agents, naphthenic acid and palmitic acid. Chemists at Harvard University and Dow Chemical developed napalm in 1942 while attempting to develop a synthetic rubber in the face of wartime rubber shortages. When first introduced for military use, napalm

was used in flamethrowers and in bombs. Napalm and Napalm B, a variation on the original formula, is a highly flammable substance that burns skin and is impossible to wipe off. Dow Chemical made napalm in the 1960s until public protest, including by chemists, forced it to cease manufacture. A Pulitzer Prize-winning photograph of Vietnamese girl Phan Thi Kim Phuc running naked down a road after being burned by napalm led to increased public outcry against napalm. In 1980, the United Nations banned the use of napalm on humans. The United States signed the ban in 2009, on President Barack Obama's second day in office.

Peg A. Lamphier

See also Drones; Petroleum Industry (Post–World War II); *Vol. 2, Sec. 1*: Dow Chemical Company

Further Reading

Thi, Kim Phuc Phan. 2017. *Fire Road: The Napalm Girl's Journey through the Horrors of War to Faith and Forgiveness*. Carol Stream, IL: Tyndale Momentum.

National Aeronautics and Space Administration (NASA)

Established by President Dwight D. Eisenhower (1890–1969) in 1958, the National Aeronautics and Space Administration (NASA) is today a group of 18 centers and facilities located throughout the nation. It has enabled scientists to reshape our understanding of the universe, engineers to improve aeronautics, the commercial sector to research and develop new products, and the public to share in the thrills of exploration and the spin-offs of cutting-edge technology. The organization has four principle organizations, or "mission directorates," that focus on aeronautics, science, space technology, and human exploration and operations.

NASA's creation was partly a product of the Cold War. In October 1957, the Soviet Union shocked the world by launching Sputnik, the first man-made satellite. Though the National Advisory Committee for Aeronautics (NACA) was considered one of the top institutions in the world for aeronautical research, the

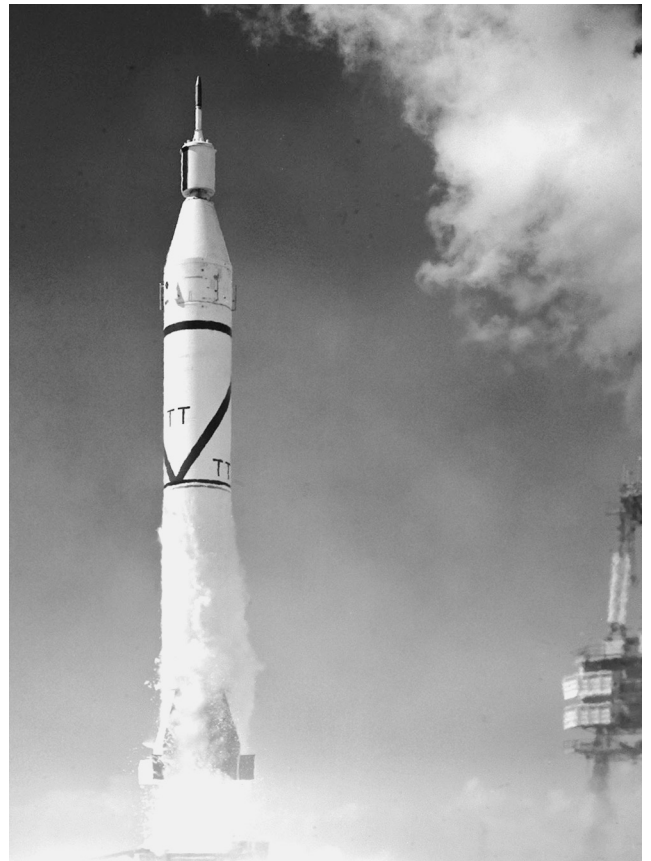
most urgent research needs for the future appeared in space. Less than one year after Sputnik, NASA became the agency to address these needs, replacing NACA. NASA's new mission was to perform basic research and development for military and civil space exploration programs.

In the 1960s, NASA became known in the eyes of the public as the home of the astronauts and their quest for the moon. This mission, known as Apollo, had its genesis in President John F. Kennedy's (1917–1963) famous "Urgent National Needs" speech in May 1961. With a goal of landing a man on the moon before the decade was out, he wanted the entire nation to commit itself to achieving this goal quickly and efficiently—and before its rival superpower, the Soviet Union, could do that. As the Mercury and Gemini projects laid the technical and intellectual groundwork for the mission, the Apollo astronauts succeeded in carrying out Kennedy's challenge. On July 20, 1969, Neil Armstrong (1930–2012) and Buzz Aldrin (1930–) became the first humans to walk on the moon. Ten others followed them in subsequent Apollo voyages.

While the astronauts garnered all the headlines, NASA developed the first weather and communications satellites, giving birth to the satellite communications industry. In 1958, Explorer 1 became America's first man-made satellite, and Explorer 9 took the first picture of Earth from space in 1959. In 1960, the Television Infrared Observation Satellite, TIROS-1, became the first weather satellite in the world. That same year, Echo 1 became the first communications satellite launched by NASA. Two years later, Friendship 7, as part of Project Mercury, became the first "manned satellite," piloted by John Glenn (1921–2016).

This put NASA into the business of launching satellites with vehicles like Atlas, Titan, and Centaur. Cost benefits to NASA were significant. Because national policy precluded satellite companies from contracting directly with the launch vehicle manufacturers for launch services, the government, which owned the vehicles, could charge the makers of commercial satellites for the use of their vehicles, launch facilities, and services. NASA reached its 100th launch in the late 1990s.

The energy crisis of the 1970s marked a turning point for the United States in a number of ways. It



The 1958 Jupiter C Explorer satellite launch was one of NASA's early triumphs. A decade later, Project Apollo, a human spaceflight program that culminated in the moon landing, overshadowed the unmanned missions. (NASA)

changed the focus of NASA's aeronautical research fundamentally. Starting with NACA and continuing with NASA, the aeronautical emphasis had been on researching and building aircraft that would fly higher, go faster, and travel farther. Today, a commercial airline requires less than half the fuel to fly the same distance as an airplane in the 1970s. Key programs established by NASA, such as the Aircraft Energy Efficiency project (ACEE), helped achieve this.

NASA has continued the NACA tradition of groundbreaking aeronautical research in other areas as well, including aerodynamics and wind shear, using advanced research tools like wind tunnels and computer simulation. The X-15 program was a rocket-powered airplane capable of leaving the atmosphere and gliding back to earth. The F-8 digital fly-by-wire program enabled the development of high-performance aircraft. Other critical

advances included supercritical wings that enabled transonic aircraft to lessen the effects of shock waves.

Another significant new direction for NASA after the Apollo missions was “space science.” Planetary probes and landers have resulted in developing the core base of knowledge about our planet neighbors. The earliest type of spacecraft designed to make these planetary voyages were the Mariner (1962–1975) class probes, which visited both Venus and Mars. Conceived in 1960, these craft carried out flyby missions of the closest planets to the earth. They paved the way for more complex orbiting missions, eventually leading to an actual planetary landing. Mariner 10, the final in this series of probes, launched in 1973. It successfully reached Venus in February 1974, taking 4,000 photos of the planet. One month later, it made its first of three flybys of Mercury.

Pioneer 10 became the first spacecraft to travel through the asteroid belt, the first to make direct observations of Jupiter, and also the first to venture outside our solar system. At a distance of 7 billion miles from Earth, it holds the distinction as the remotest object constructed by humans. Now heading toward the Taurus constellation, it will take 2 million years to pass by one of the stars there. Pioneer 11 now drifts as a ghost ship headed for the Aquila constellation, which it will reach in 4 million years. Because of the potential contact with other beings on its long journey, American astronomers Carl Sagan (1934–1996) and Frank Drake (1930–) designed a plaque indicating who sent it. It displays a nude man and woman stand in front of a drawing of the spacecraft, along with a schematic of the earth’s position in the solar system.

NASA’s next planetary achievement was to land probes on the surface of another planet, and the first to do so were the Viking missions to Mars. Viking I and its sister ship Viking II, both launched in 1975, each consisted of an orbiter and a lander. The orbiters returned 52,603 images of the planet covering the entire Martian surface during all of its seasons. These photos also included images of both of the Mars moons. Other orbiter investigations included: water vapor mapping; thermal mapping; and data on ionospheric properties, atmospheric composition, and atmospheric structure. Lander investigations included: biological data; molecular analysis; inorganic analysis;

meteorology; seismology; magnetic properties; physical properties; and radio science that included celestial mechanics, atmospheric properties, and a test of general relativity.

Launching in 1977, *Voyager 1* and its counterpart, *Voyager 2*, gathered the most detailed and scientifically relevant knowledge ever assembled about Jupiter, Saturn, Uranus, Neptune, and the outer solar system. As luck would have it, these probes were in a perfect position to take advantage of a natural phenomenon that occurs once every 176 years. In the late 1970s, the largest planets in the solar system literally lined up to one side of the sun. Scientists knew that a carefully timed spacecraft sent from Earth could take advantage of this configuration and make an unprecedented tour of the planets in a single voyage. They provided the first detailed visual and scientific studies of the Jovian and Saturnian systems as well as the first close encounters with the outer solar system planets.

By the 1980s, NASA had turned much of its attention away from the expendable launch vehicle program and toward the space shuttle and low-earth orbit. Many engineers lamented this decision, as NASA was essentially forsaking two decades of reliable expendable rockets for a new system that had not launched even once and promised only minor advantages, along with the risky disadvantages of deploying satellites from a human-piloted ship. The *Challenger* disaster served as the catalyst for the commercialization of the expendable launch vehicle industry.

Orbiting space telescopes were the most dramatic scientific contribution by NASA to space science in the 1990s. But it also continued its planetary probes with Mars Pathfinder, which landed on Mars in 1997. To better explore the planet, it used a rover named Sojourner to investigate beyond the landing site with spectrometry to analyze rocks and soil. In 2012, two additional rovers, Opportunity and Curiosity, began to further explore the planet, discovering clear examples of a Mars that once had rivers and lakes, as well as an environment that could have supported microbial life. Mars Odyssey, Mars Express, and the Mars Reconnaissance Orbiter currently send back data from their orbital vantage points.

NASA is also significantly involved in better understanding life on earth. In 1999, it launched Terra

as the first of the Earth Observing System craft. Terra's mission is to better understand the changing climate on earth through five sensors that investigate interactions between the ocean, land, the atmosphere, and radiant energy. Aqua is another earth science satellite, and, as its name indicates, its focus is on the earth's water cycle.

At the start of the 21st century, NASA made a giant leap into space with the International Space Station (ISS). This effort capitalized on the success of Skylab, the United States' first orbiting station. Launched in 1973 atop a Saturn V rocket, Skylab proved that humans could live and work in a zero-gravity environment for several months at a time. Skylab also photographed the earth and returned astronomical observations with its Apollo telescope mount. Its mission ended in 1979 when Skylab reentered and burned up in the earth's atmosphere over Australia.

Unlike Skylab, the International Space Station (ISS) has truly been an international endeavor, with contributions from NASA, the Russian Federal Space Agency, the European Space Agency, the Japan Aerospace Exploration Agency, and the Canadian Space Agency. Each of these agencies built various modules for the ISS, and when each was completed, a space shuttle or Soyuz capsule delivered it to orbit. The International Space Station received its first human residents on November 2, 2000. Since that time, over 200 people, in crews of 6 at a time, have taken shifts on the station. On its 10th year in flight, it had logged over 1.5 billion miles and orbited the earth over 57,000 times. The NASA Authorization Act of 2010 established the American goals for the ISS, which include "human health and exploration, technology testing for enabling future exploration, research in basic life and physical sciences, and earth and space science."

Today, NASA divides its interests into four main mission directorates. The Aeronautics Research Mission Directorate (ARMD) works on improving the U.S. air transportation system (safety, environmental impacts, and air traffic congestion) and also furthering green aviation (increased fuel efficiency, better flight planning, lower emissions, and reduced noise). The Human Exploration and Operations (HEO) Mission Directorate concentrates on tasks in and beyond

low-earth orbit, including the International Space Station, space life sciences, and advanced exploration systems. The Space Technology Mission Directorate (STMD) develops new technologies that NASA needs to achieve its space missions through partnerships with industry and academia. Finally, the Science Mission Directorate investigates the relationship between the earth and the sun, the solar system, and the universe.

These missions are carried out at the following 10 NASA centers and 8 facilities:

- Ames Research Center: Mountain View, CA
- Armstrong Flight Research Center: Edwards, CA
- Glenn Research Center: Cleveland, OH
- Goddard Space Flight Center: Greenbelt, MD
- Goddard Institute for Space Studies: New York, NY
- Independent Verification and Validation Facility: Fairmont, WV
- Jet Propulsion Laboratory: Pasadena, CA
- Kennedy Space Center: Cocoa Beach, FL
- Langley Research Center: Hampton, VA
- Marshall Space Flight Center: Huntsville, AL
- Michoud Assembly Facility: New Orleans, LA
- NASA Shared Services Center: Kiln, MS
- Plum Brook Station: Sandusky, OH
- Stennis Space Center: Hancock County, MS
- Wallops Flight Facility: Wallops Island, VA
- White Sands Test Facility: Las Cruces, NM

The future promises a bold program of new exploration, cutting-edge technology, and scientific research. The Orion spacecraft and the Space Launch System rocket plans to send astronauts to an asteroid in the 2020s and to Mars in the 2030s. NASA continues to work with commercial companies to develop spacecraft to transport astronauts and cargo to low-earth orbit. In aeronautics, it is part of a government team to create the Next Generation Air Transportation System (NextGen) that will fly in 2025.

Mark D. Bowles

See also Skylab; *Vol. 2, Sec. 2*: National Advisory Committee for Aeronautics (NACA); *Vol. 3, Sec. 2*: Space Shuttle; *Vol. 3, Sec. 3*: Hubble Space Telescope; International Space Station

Further Reading

Bilstein, Roger E. 2003. *Testing Aircraft, Exploring Space: An Illustrated History of NACA and NASA*. Baltimore: Johns Hopkins University Press.

Dick, Steven J., and Roger D. Launius. 2006. *Critical Issues in the History of Spaceflight*. Washington, D.C.: National Aeronautics and Space Administration, Office of External Relations, History Division.

Primary Document: Letter of President Dwight Eisenhower to Keith Glennan, Retiring Administrator for NASA (1960)

On December 29, 1960, President Dwight Eisenhower wrote a letter to Keith Glennan, the retiring administrator for NASA who had held the title since its founding in 1958. In the letter, the president praises Glennan for the many accomplishments he shepherded into existence in his tenure, including launching satellites and deep space probes.

December 29, 1960

Dear Keith:

Under your leadership, the National Aeronautics and Space Administration, since its inception on October 1, 1951 has compiled a record of achievement of which every American can be justly proud. Therefore, while accepting your resignation as Administrator of NASA, effective January 20, 1961, I wish to express my thanks for the great contribution you have made.

Our Nation's non-military aeronautical and space activities are vastly expanding human knowledge phenomena in the atmosphere and outer space and applying this knowledge for the benefit of all mankind. The progress that is being made is striking testimony to your ability to quickly bring together an effective and dedicated staff, to plan an imaginative program of space exploration, and to implement this plan with vigor and determination.

In little more than two years, NASA has successfully launched meteorological satellites, such as Tiros

and Tiros II, that promise to revolutionize methods of weather forecasting; demonstrated the feasibility of satellites for global communications by the space-shot launching of Echo I; produced an enormous amount of valuable scientific data such as the discovery of the Van Allen Radiation Belts; successfully launched deep-space probes that have established the greatest range over which man has tracked, and made gratifying progress toward the goal of manned space flights.

Because of the organization and program you have helped to create, Americans can look forward to a remarkable time in space exploration. It is hard to realize—yet inexorably true—that the near future will hold such wonders as the orbital flight of an astronaut, the landing of instruments on the moon, the launching of the giant Saturn, and the reconnaissance of Mars and Venus by unmanned vehicles.

As you return to private life, you carry with you my appreciation, respect, and friendship. I wish you a long, happy, and healthy future.

DWIGHT D. EISENHOWER

The Honorable T. Keith Gisanan
Administrator

National Aeronautics and Space Administration
Washington, D. C.

Source: Eisenhower Presidential Library and Archives.

National Science Foundation (NSF)

As a counterpart to the National Institutes of Health (NIH), whose headquarters currently reside in Arlington, Virginia, the National Science Foundation's (NSF) mission statement notes that its purpose is "to promote

the progress of science; to advance the national health, prosperity, and welfare; and to secure the national defense." As an independent federal agency established by the U.S. Congress in 1950, the NSF's goals are to strategically cultivate knowledge among *nonmedical* areas of science and engineering—this is where it

differs from the NIH. It focuses on the study of these two fields and also supports education within them.

Before World War II, the study of science and engineering was not a concern for the government. It left that in the hands of private and philanthropic foundations. Military research was unorganized and not well communicated; redundant studies might be done because nobody knew if others had researched the same topics. The National Science Foundation was created once the nation saw that the organized study of science, technology, and education was crucial to society.

The United States saw that science and engineering had aided in its World War II victory and created the NSF to promote the welfare of society. President Harry S. Truman signed it into existence on May 10, 1950 with the NSF Act. With it also arose a National Science Board, which included a director and 24 part-time members. The following year, President Truman nominated Alan T. Waterman as the first director of the NSF.

The NSF offers grants, but contrasting with its medical counterpart, it does not have a lab. It receives over 50,000 proposals annually in fields that include mathematics, computer science, and other sciences and has a budget of \$7.5 billion; it funds only 20 percent of proposals. A proposal review consists of three phases: proposal preparation and submission (Phase 1), proposal review and processing (Phase 2), and last, award processing (Phase 3). Phase 1 takes up to 90 days from the announcement of a funding opportunity. Phase 2 takes up to six months, and consists of reviews by the NSF leadership. Phase 3 lasts up to a month; the Division of Grants and Agreements coordinates more reviews, making sure that the request has been rightfully rewarded, finalized, and notified.

Since the early 1950s, the NSF has strengthened undergraduate teaching, funding many programs and schools. In June 1953, the NSF supported its first colleges by sponsoring four science institutes to encourage summer research, and it has since provided funds for programs for physics, biology, and mathematics. Tufts University became one of the earliest colleges to accept funding from the National Science Foundation for this purpose. The NSF believes that it is crucial for students to study subjects such as computer science, mathematics, chemistry, and more.

Director and astronomer Dr. France A. Cordova, a former president of Purdue University, joined the NSF in March 2014. Currently, about 2,100 people work at the foundation.

Hiba Mouri

See also *Vol. 2, Sec. 1*: National Institutes of Health (NIH)

Further Reading

Morrison, Jessica. 2014. "Incoming NSF Director Faces Challenges in Congress: Former Purdue University President France Cordova Inherits an Agency at a Crossroads." *Nature* 507, no. 7492: 285.

A Report to the Science and Technology Policy Office, National Science Foundation on Increased Productivity from Animal Agriculture. 1976. Ithaca, NY: Agricultural Experiment Stations, New York State College of Agriculture and Life Sciences, Cornell University.

Strategic Guidance for the National Science Foundation's Support of the Atmospheric Sciences: An Interim Report. 2005. Washington, D.C.: National Academies Press.

Noyce, Robert (1927–1990)

Robert Noyce, an entrepreneur, physicist, and inventor, played a key role in the development of the integrated circuit, which is one of the most fundamental technologies that today's computers are built around. He is also a cofounder of Fairchild Semiconductor and Intel Corporation, landing him the nickname "mayor of Silicon Valley."

Noyce was born in Burlington, Iowa, on December 12, 1927, the youngest of four brothers, to Ralph Brewster and Harriet May Norton. The Noyce family moved to Atlantic, Iowa, after Noyce's birth and then to Decorah, Iowa, when he was eight years old. After two years, they moved to Webster City, Iowa, and to Grinnell, Iowa, two years after that. Noyce spent the remainder of his childhood in Grinnell. Bored with high school physics, he took a college-level physics course, inspired to do so by a Grinnell College physics professor whose lawn he mowed. Noyce's parents

moved to Sandwich, Illinois, after he graduated high school; Noyce remained at Grinnell College.

Noyce excelled at college academics and extra-curriculars such as the swim team and theater. He graduated with honors, with a BA in physics and mathematics in 1949. Noyce was exposed to one of the first ever transistors in one of his physics classes, which is what sparked his passionate interest in the subject. He would go on to base his 1953 MIT PhD dissertation on transistors.

Noyce was not the only one in his family with an interest in technology and physics. One of his brothers taught chemistry, and another worked for IBM in San Jose, California. His third brother, perhaps influenced by their father, joined Yale's Divinity School to study theology.

After completing his education, Noyce scheduled interviews at IBM, RCA, GE, Bell Labs, and more. Philco was trying to get into the transistor business and hired Noyce in 1953. He felt that the company lacked scientific talent aside from himself and some other PhDs who had been hired shortly after him. In 1956, Bill Shockley, known as the inventor of the junction transistor, recruited Noyce to work in his semiconductor laboratory. Noyce moved to California to work under Shockley, but he was frustrated with Shockley's management skills. Noyce and seven of his peers splintered off and started what would become Fairchild Semiconductors Corporation in Santa Clara, California.

There, he presented his concept of the integrated circuit, and Fairchild believed it would revolutionize electronics, taking it on as a core mission. Noyce and his colleagues created the first ever integrated circuit (IC), a complete circuit contained on a wafer of silicon—more commonly known as a “chip.” Noyce and Jack Kilby received the patent for this piece of technology.

Noyce stayed with Fairchild as its director of research and development until 1968, when he and two coworkers, Andrew Grove and Gordon Moore, founded Intel Corporation to make microprocessor chips. These components can be thought of as the brains of modern computers. Along with processing arithmetic, microprocessors control all the functions of a computer system. Noyce worked in various upper-executive positions at Intel up until 1978, when he transitioned to the position of chairman at the Semiconductor Industry Association.

Noyce's several inventions and innovations over the course of his life earned him many awards from the scientific community, including the IEEE Medal of Honor in 1978 and the Charles Stark Draper Prize from the National Academy of Engineering. He was also awarded the National Medal of Technology by President Ronald Reagan in 1987. If not for the innovations that Noyce and his colleagues created, technology might be decades behind where it is today in the Digital Age.

Noyce married twice. He had four children with his first wife, Elizabeth Bottomley, who had studied English at Tufts University in Medford, Massachusetts. They met when she directed a drama project and married in 1953. Late in 1974, Noyce left Elizabeth to marry an Intel executive, Ann Bowers. The two would stay together until Noyce succumbed to death in 1990 of a heart attack.

Rosanne Welch

See also Integrated Circuit; Intel Corporation

Further Reading

Berlin, Leslie. 2005. *The Man behind the Microchip: Robert Noyce and the Invention of Silicon Valley*. Oxford: Oxford University Press.

Primary Document: Personal Interview with Robert Noyce for the IEEE History Center (1975)

This is a transcript of a personal interview with Robert Noyce for the IEEE History Center in Hoboken, New Jersey, conducted in 1975 by Michael Wolff. The interview goes into great detail about Robert

Noyce's involvement with the creation of electrical components that are critical in our world today—mainly the integrated circuit and advancements in transistor technology. This document is important

because it gives a firsthand account of the integrated circuit's invention and experimentation, as well as what motivated Mr. Noyce and his colleagues to create this important piece of technology. The interview also goes into Robert Noyce's personal background and what got him interested in physics.

Wolff:

Let's go back to the actual invention. When did it get invented? I don't mean the date, but what was the critical step? It was after you had the planar technology.

Noyce:

Yes.

Wolff:

Can you retrace who thought what or said what to whom or did what and where you fit in this?

Noyce:

We were having a review of the patent application on the planar transistor, as I recall. John [Lippincott J.] Ralls was there. He was Fairchild's patent attorney at the time. We were thinking that we ought to try to cover as broad an area as possible out of this development. We sort of assigned our selves to the task of doing what we could, in conceptualizing, to cover as broad an area as we could with that. That was in the back of our minds anyway, but I suppose that the actual invention came down to the point where one day one comes in to the lab and says, "Hey, here's a good way to do this. Why don't we do it this way?" I'd have to look up the actual data, but it was probably back in '59.

Wolff:

Without trying to recall the date can you recall the circumstances and tell me about that day?

Noyce:

I did not see it as a very unusual day. I just went in and probably had a discussion with Gordon Moore or Vic Grenich or somebody like that initially. I said something like, "Hey, here's a way to do the whole job of making some logic circuits instead of making individual transistors." There wasn't any need for describing what the utility of the thing would be around that shop. That was well known. It was a question of coming up with a compatible set of schemes to come up with the structures that would work electrically. Then we proceeded to try to realize the structures and file patent applications on it.

Wolff:

Let's try to tie down the organization here. What was your position at that time and who was "we"?

Noyce:

Fairchild was still a pretty tightly knit little group at that time. There were the eight founders that had been in there. Obviously the staff had expanded, but most of the technical work was being done by that group of eight founders, which included Sheldon Roberts who was a metallurgist, Jean Hoerni who was a physicist, Gordon Moore who was a chemical physicist, Vic Grenich who was in electronics, Jay Last who was a physicist and myself. And there were a couple of engineers.

Wolff:

You were a physicist.

Noyce:

I was a physicist by training, and had my training in solid-state physics. More accurately it was physical electronics. Solid-state physics was not yet a respectable field at MIT. We were a tightly knit little group. We had worked together at Shockley and knew each other pretty well. There was an awful lot of batting of ideas back and forth and criticism of other people's ideas, "Hey, that won't work because of this." Then we'd go back and say, "Well, let's devise a scheme that will work." It was a question of having rather vague concepts of insulators, isolation, interconnection and the photoengraving for the pattern. We drew on our bag of tricks these particular elements. Those elements in combination made the integrated circuit. Perhaps there was the "I've got it" type of thing, there is a way that will work. Once you have a way that will work conceptually then you start refining it to make it work better. Up until this point it was sort of, "Gee, wouldn't it be nice if you could?"

Wolff:

Was there such a moment like that on this day that you recall as being ordinary?

Noyce:

Yes. I remember sketching it out on the blackboard for John Ralls, who was the patent attorney. Did I do it some other time for the other people? Very likely not on the blackboard, but I probably said, "Hey, why don't we do this."

Wolff:

What did you sketch for Ralls?

Noyce:

The sketch I did for Ralls was very similar to what is in the patent application.

Wolff:

Do you mean the patent for the planar transistor?

Noyce:

No. I mean the one for the integrated circuit patent. It shows the various elements and how they are constructed conceptually. It shows the transistor, the diode and the resistor as being three elements that we could make easily at that time.

Wolff:

I just lost the thread here because you had been talking about a meeting with Ralls to discuss the planar transistor.

Noyce:

Yes. No, this was a later one then. It was after he was throwing out the challenge as to what could be done with it beyond that—as any good patent counsel does.

Wolff:

You remember him throwing out the challenge.

Noyce:

Yes.

Wolff:

Then you began thinking about circuits.

Noyce:

Yes. Thereafter there was the insight that with the addition of that insulating layer the circuits could be done. There were a couple of other incidental inventions that came along at that time which were more critical to the immediate task that we had at Fairchild. We were trying to make high-frequency transistors. One of the problems with high-frequency transistors was that the structures were extremely small and contacts had to be made to extremely small areas. One of the first concepts in there that was patented was, “Okay, let’s make a big contact but have the metal film over this silicon dioxide—which is the insulator—and have a hole in the silicon dioxide that is very small to make a contact through this very small area.” That patent was filed, and after that immediately came the idea, “A metal strip can be put over the PN junction without shorting it out.” As soon as that can be done the entire circuit can be interconnected. It was a progressive buildup of the bits and pieces of the technology that made the entire thing possible.

Source: Robert Noyce, an oral history conducted in 1975 by Michael Wolff, IEEE History Center, Hoboken, New Jersey. Available at: http://ethw.org/Oral-History:Robert_N._Noyce

Nuclear and Radiation Accidents

The International Atomic Energy Agency (IAEA) defines a nuclear or radiation accident as any incident that creates significant consequences to a facility, the environment, or people. To date, the worst nuclear accident happened at the Chernobyl plant in Ukraine in 1986. According to the IAEA, the United States has experienced 12 nuclear accidents that have resulted in multiple fatalities or over \$100 million in damage. Radiation accidents and incidents are too numerous to count.

A number of political measures sped nuclear power’s development in the post–World War II period. Although nuclear power held many promises, it also contained inherent dangers. Nuclear fission in a reactor releases heat, which is carried away by coolant (usually water, gas, or liquid metal) to heat water and

create steam to turn turbines and produce electricity. Control rods pushed into a reactor regulate the amount of heat produced in a reactor by absorbing the neutrons that cause fission. But if the heat within a reactor exceeds that being carried away by coolant, components of the reactor can begin to melt, releasing heat and radioactivity and possibly causing explosions if the energy released is too great.

The EBR-I reactor in eastern Idaho became the first functional nuclear power plant in December 1951 when it produced enough electricity to power four lightbulbs. Yet, during extended experimentation with this early design, scientists there became puzzled by unexpected responses to changes in coolant flow within the reactor. In November 1955, during coolant flow tests, the reactor partially melted down. Researchers discovered that the unanticipated changes had been caused by unforeseen expansion of the uranium fuel

rods within the reactor, and the reactor was repaired for further operation.

Another partial meltdown occurred in July 1959 at the Sodium Reactor Experiment in Simi Valley, California, which used liquid sodium as a reactor coolant. (Water used as reactor coolant must be subjected to high pressure, but liquid sodium does not require this stipulation.) The oil-like fluid tetralin was used in a support system to cool and stabilize the pump removing heated sodium from the reactor. But when tetralin seeped into the coolant system itself, the molten sodium decomposed the oily substance, leading to the clogging of several channels designed to remove heat from the reactor. The resulting overheating damaged many of the reactor's fuel components. Operations continued for several days until reactor staff noticed unusual behavior, at which point the reactor was shut down. Inspectors found that several pieces of the fuel elements had dislodged and either gotten stuck in the reactor's transport systems or fallen to the floor of the reactor. Over the following months, Atomics International, the private company managing the reactor, cleaned and repaired the reactor and installed a new core, with operations resuming in September 1960.

Later accidents were more serious in scope. On January 3, 1961, the SL-1 reactor located at a U.S. Army facility in eastern Idaho was being prepared for reactivation after an extended shutdown over the Christmas and New Year's holidays. The main control rod in the reactor needed to be withdrawn a few inches from the reactor to be reattached to its drive mechanism. The rod was suddenly withdrawn several inches too far, causing the inside of the reactor to immediately heat to extreme temperatures and vaporize the water inside the reactor. The pressure generated caused the other control rods to shoot out of the reactor and even made the entire reactor jump over nine feet in the air. The operator who had removed the main rod was killed almost instantly, another employee was impaled by a control rod, and one more was found unconscious nearby. Though a number of theories circulated about why the rod was suddenly withdrawn, investigators determined that the most likely explanation was that it had broken loose and been removed by accident. The site's remote location in the Idaho desert, combined with the SL-1's building's containment capabilities,

limited the threat of broader radioactive exposure, though the incident remains the only known U.S. nuclear meltdown that resulted in immediate fatality. As a consequence of the incident, the army shut down the reactor and buried the remains, and future nuclear designs for both public and private plants were designed to ensure that the removal of a single control rod could not generate the amount of excess heat that had caused the accident.

As nuclear incidents grew more severe in scope and attracted media attention, many Americans began to reconsider the viability of nuclear power. In the late 1960s and early 1970s, a burgeoning environmental movement that demanded new rules for clean air and clean water folded nuclear power into its list of environmental concerns. Observers such as plant physiologist Barry Commoner and consumer advocate Ralph Nader, along with others, pointed out that no energy source presented the risk of sudden and catastrophic disaster that nuclear power did. The 1966 partial meltdown of Fermi-1 in Detroit inspired local newspaper writer John G. Fuller's *We Almost Lost Detroit* (1975), a visceral account of the accident and the extended, troubled repair process. The 1975 fire at the Browns Ferry plant in Alabama resulted in enhanced fire protection standards for nuclear plants but did little to quell rising antinuclear protest.

Proponents and detractors of nuclear power also argued vociferously about the disposal of used radioactive nuclear material. Antinuclear advocates were skeptical that used material could be contained, predicting that it would escape underground containment vessels and make its way back to the surface and into the water supply. Few Americans wanted spent nuclear rods buried anywhere near their towns or cities.

Disillusioned observers inside the industry itself also took their concerns to the news media. Karen Silkwood, an Oklahoma nuclear power worker, died in a car accident while delivering evidence of misconduct at her workplace to a *New York Times* reporter, which brought accusations of corporate foul play from antinuclear activists. In 1976, three senior nuclear engineers turned against their employers, accusing the industry of lax adherence to safety standards and charging the Nuclear Regulatory Commission (which had replaced the Atomic Energy Commission in a

1974 government reorganization) of working hand in hand with private companies to conceal evidence of safety violations. The television newsmagazine *60 Minutes* ran a story about one of these industry whistleblowers, bringing the allegations to the attention of the general public.

The most serious nuclear accident in the United States, the March 1979 Three Mile Island disaster in Pennsylvania, most directly led to the decline of the U.S. nuclear power industry. The incident combined all of the potential fears about nuclear danger: technical malfunction in the form of a stuck valve, poorly trained operators who could not tell that the reactor's relief mechanism was not working properly, and incompetent management that did not know that a meltdown was occurring until it was well underway. President Jimmy Carter, who toured the plant with Pennsylvania's governor that April, established a special committee to investigate the accident. The resulting report laid heavy blame upon both the plant's private operators and NRC regulators.

Though the meltdown caused no immediate fatalities, nearly 140,000 Pennsylvanians evacuated their homes due to concerns about radioactive exposure, and the cleanup lasted over 14 years, with costs reaching \$1 billion. Stalwart nuclear proponents like physicist Edward Teller and Oak Ridge National Laboratory head Alvin Weinberg attempted to assuage Americans' fears by pointing out that no one had died in the accident and that the release of toxic radiation had been minimal. Nuclear advocates conceded that the American regulatory structure needed reform, pointing to France and Japan as examples of nations where the nuclear power system had been safely and competently established. But the multiple levels of failure on display at Three Mile Island were too much for the public to stand, as protests persisted in the United States and around the world. Public opinion in the United States turned sharply against nuclear power as a result of the accident (with the 1986 Chernobyl catastrophe in Ukraine raising nuclear fears to even higher levels), and no new nuclear power plants were approved for construction in the United States until 2012.

A number of smaller accidents at nuclear plants occurred steadily after 1979. In January 1982, for

example, a steam tube rupture at the Ginna Nuclear Generating Station in Ontario, New York, released radioactive material into the environment. At the Nine Mile Point station in Scriba, New York, malfunctions forced a plant shutdown in December 1987, and safety concerns spurred the shutdown of the FitzPatrick reactor in the same city in November 1991. In March 1993, equipment failures shut down Sequoyah Unit 1 in Soddy Daisy, Tennessee. Unmonitored wear and tear on reactors as the years passed generated a further source of concern.

After the 2011 Fukushima Daiichi disaster in Japan galvanized renewed worldwide fears, an annual survey of American utility executives identified nuclear safety as the number-one concern within the power industry, and license extensions for existing American reactors were expected to come under enhanced scrutiny.

In 2012, the Union of Concerned Scientists, a nonprofit advocacy organization, claimed that the leakage of radioactive materials was a significant problem for 90 percent of American power plants. The Natural Resources Defense Council, the National Wildlife Federation, the Sierra Club, and other environmental groups continued their antinuclear protests, which had hardly lulled since Three Mile Island. Though there were no major nuclear meltdowns in the United States after 1979, the combination of sporadic equipment failures and human error meant that a variety of problems persisted in the industry.

William Michael Camp

See also Vol. 2, Sec. 3: Atomic Bombs/Nuclear Weapons; Manhattan Project; Vol. 3, Sec. 2: Nuclear Energy/Nuclear Power Plants

Further Reading

- Camilleri, J. A. 1984. *The State and Nuclear Power: Conflict and Control in the Western World*. Brighton, UK: Wheatsheaf.
- Nader, Ralph, and John Abbotts. 1977. *The Menace of Atomic Energy*. Collingwood, Australia: Outback Press.
- Walsh, Edward J. 1988. *Democracy in the Shadows: Citizen Mobilization in the Wake of the Accident at Three Mile Island*. New York: Greenwood Press.

Ochoa, Ellen (1958–)

Dr. Ellen Ochoa is an American scientist, inventor, and astronaut, and the current director of the Lyndon B. Johnson Space Center (JSC) in Houston, Texas. She was the first female Hispanic astronaut to go into space and the first Hispanic person to head the JSC.

Ochoa was born in Los Angeles, California, but was raised in La Mesa, California, a suburb of San Diego. Her parents were divorced when she was a teen. Ochoa's mother attended college while raising her four children, providing inspiration for Ochoa's academic success.

Ochoa graduated from Grossmont High School in 1975 as the class valedictorian. A classically trained flutist, she considered pursuing a music degree in college, but she decided to study science because many of her friends from her high school calculus class were planning to major in science and engineering. While pursuing advanced studies in science, Ochoa maintained her involvement with music, receiving the student soloist award from the Stanford Symphony Orchestra as a graduate student. She earned her undergraduate degree in physics at San Diego State University (1980). She went to graduate school at Stanford and earned her master's degree in 1981 and her doctorate in electrical engineering in 1985. She then accepted a position as research engineer at the Energy Department's Sandia National Laboratories in Livermore, California, working in the Imaging Technology Branch on optical inspection systems.

In 1987, Ochoa was accepted for the NASA training program, one of 100 finalists out of 2,000 applicants. The next year, she began work for NASA as the chief of the Intelligent Systems Technology Branch at the Ames Research Center in California, working on computational systems for space missions. Ochoa began her yearlong training process as an astronaut in 1990. Ochoa has flown in space four times, for a total of over 978 hours in orbit. Her first space flight was in 1993, when she was stationed aboard the space shuttle *Discovery* for a nine-day mission. The objective of the mission was to learn how solar activity affects the earth's climate and environment by conducting a variety of atmospheric and solar studies. One of Ochoa's tasks was to deploy and capture the Spartan satellite, which studied the sun's

corona and solar winds, using the 50-foot Remote Manipulator System (RMS) robotic arm.

The sun proved the focus of Ochoa's second space flight in 1994. She served as the payload commander on the STS-66 Atlantis Atmospheric Laboratory for Applications and Science-3 mission. During this flight, the crew continued investigations into the sun's energy during an 11-year solar cycle to determine how these fluctuations might affect the earth's climate and environment. Ochoa used the RMS again during this mission, this time to retrieve the CRISTA-SPAS atmospheric research satellite.

Ochoa's third space shuttle mission on the *Discovery* in 1999 was significant for the being the first time that the shuttle docked to the International Space Station. She visited the International Space Station for a second time during her final space shuttle mission on the *Atlantis* in 2002. During this mission, she and crewmembers Dan Bursch and Carl Walz used the station's robotic arm to install the S-Zero Truss and to maneuver spacewalkers around the station.

In 2002, Ochoa became the deputy director of flight crew operations at the Johnson Space Center, NASA's human space exploration division, and in 2006, she took on responsibility as the director of flight crew operations. Since 2012, she has served as director of the Johnson Space Center.

Ochoa also serves on the board of Service Corporation International, is an ex-officio board member of the Houston Technology Center and the Bay Area Houston Economic Partnership, and is director emerita of the Manned Space Flight Education Foundation Inc., which operates Space Center Houston. She is also chair of the Nomination Evaluation Committee for the National Medal of Technology and Innovation.

Ochoa has been awarded numerous honors including the Distinguished Service Medal, the Exceptional Service Medal, the Outstanding Leadership Medal, and four Space Flight Medals from NASA. Other awards include the Harvard Foundation Science Award, the Women in Aerospace Outstanding Achievement Award, the HENAAC (Hispanic Engineer National Achievement Awards) Engineer of the Year, the Hispanic Heritage Leadership Award, membership in the California Hall of Fame, and San Diego State University Alumna of the Year. In addition, she has

four schools named after her: two in California, one in Texas, and one in Washington State.

Terry Steagall

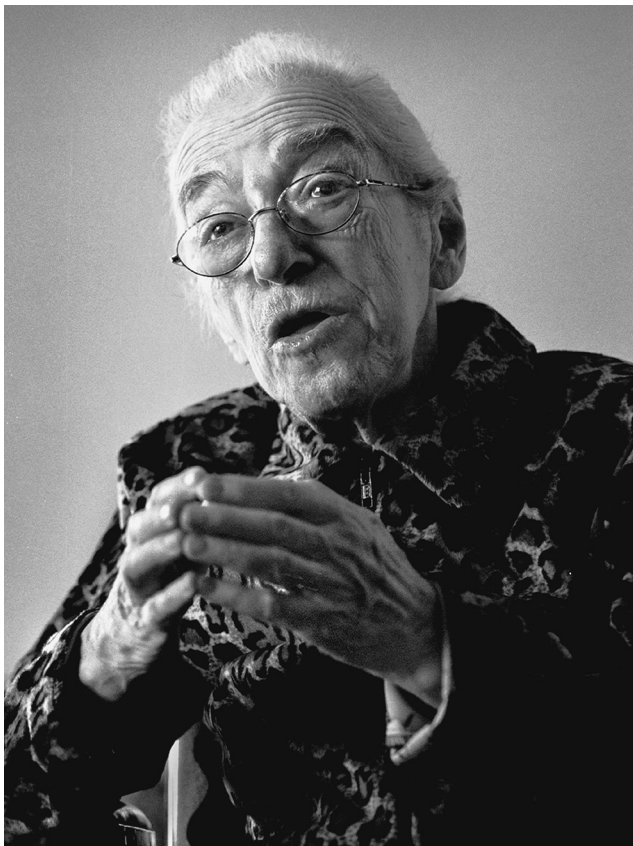
See also Apollo Project; National Aeronautics and Space Administration (NASA); *Vol. 3, Sec. 2: Space Shuttle*; *Vol. 3, Sec. 3: Mars Rover Series*

Further Reading

Williams, KatiAnne. 2011. "Making Space for Women." *Women in Engineering Magazine*, IEEE 5, no. 2: 16–20.

Orshansky, Mollie (1915–2006)

Mollie Orshansky, also known as "Ms. Poverty," was responsible for the research in food economics that developed the federal government's poverty thresholds. These thresholds track the estimated number of people



Economist and statistician Molly Orshansky developed the Orshansky Poverty Thresholds, which used nutrition statistics to calculate cost of living, to determine poverty rates. (Michael Williamson/The Washington Post/Getty Images)

in the United States living in poverty. She differentiated the thresholds not only by family size but also by farm/nonfarm status, the gender of a family's head, the number of family members who were children, and aged/nonaged status.

Mollie Orshansky was born in New York City to Ukrainian immigrant parents. She grew up in poverty and later said that her family often did not have enough food. She was the first in her family to graduate from high school and the first to attend college. She graduated from Hunter College in 1935 with an AB in mathematics and statistics. She also studied economics and statistics at the Department of Agriculture Graduate School and at American University.

After graduating from Hunter College, Mollie Orshansky worked for the Department of Health in New York City as a statistical clerk. In 1939, she moved to Washington to take on the same position for the U.S. Children's Bureau, which handled all matters pertaining to the welfare of children in the United States. She would work in a number government agencies over her career, including the National War Labor Board, U.S. Wage Stabilization Board, and U.S. Department of Agriculture (USDA).

Before her work as a food economist, she developed food plans in unison with the USDA that led to the creation of "poverty lines," which were amounts of income below which a family could be considered poor and in need of help. She accomplished this by collecting and analyzing food consumption data and tracking the expenditures of American households.

President Lyndon Johnson declared a "War on Poverty" in 1964 that utilized Orshansky's work. Johnson's administration hoped to reduce the national poverty rate, which stood at 19 percent. Orshansky was working at the Social Security Administration in the Office of Research and Statistics at the time, and her work was published in the Social Security Bulletin. The Office of Economic Opportunity used Orshansky's work as a guideline to determine the official federal definition of poverty. Her efforts won her the Commissioner's Citation from the Social Security Administration in 1965 and the Distinguished Service Award from the U.S. Department of Health, Education, and Welfare for her leadership.

Orshansky's thresholds provided the country with a means of identifying the groups in our society with the least resources. Her work laid a foundation for

methods of research in the field of statistical poverty analysis. The thresholds she developed are updated every year by the U.S. Census Bureau.

Omar Pelcastre

See also Graham, Bette; Jackson, Mary Winston; Liskov, Barbara; Morgan, Mary Sherman; Rocket Girls of JPL; Wise, Brownie

Further Reading

Gilbert, Geoffrey. 2008. *Rich and Poor in America: A Reference Handbook*. Santa Barbara, CA: ABC-CLIO.

Orshansky, Mollie. 1965. "Counting the Poor: Another Look at the Poverty Profile." *Social Security Bulletin* 28 (January): 3–29.

Packet Switching

Packet switching is the concept of breaking down information into smaller pieces to be sent independently through various channels and reassembled into original order at the destination. The concept was first introduced by a Department of Defense research program at the Rand Corporation and was originally called "distributed adaptive message block switching" by its inventor, Paul Baran, in the 1950s. Donald Davis coined the term "packet switching" when he independently introduced his research in the concept of small block data transmission networks at the National Physical Laboratory in the United Kingdom in the 1960s.

Both basic concepts focus on creating robust and reliable data communication networks to more efficiently transmit large volumes of data from different applications simultaneously, even after network nodes are attacked or taken offline. Over time, the concept of packet switching in networks led Leonard Kleinrock to help in the development of ARPANET, the network that would eventually evolve into what we know as the Internet.

Before the concept of packet switching in networks, communication networks had limited efficiency due to the necessity for network channels to stay connected for the duration of the entire transmission. Packet switching avoids this by breaking down the information into limited byte-size pieces composed of

two basic parts: the header and the payload. The header contains information about the source, destination, and metadata used by the network to direct the packet through the network to the specified destination. The payload is the actual information intended for use at the specified destination.

Since the introduction of packet switching, the concept has spurred the creation of a variety of different networks, all with unique operating procedures, computing languages, and network configurations, which proved difficult for network-to-network communication. This challenge was addressed using Kleinrock's queueing theory, via Internet Protocol suite (also known as TCP/IP, transmission control protocol, and Internet Protocol). Also known as metadata, the TCP/IP provides error corrections and organization for reliable data transmission. Using a variety of algorithms, metadata also provides detailed controls and instructions about the payload delivery, such as delivered data arrangement, key payload elements, file type, information source, who can access the payload, and other technical network navigation protocols.

Modern Internet connectivity emerged with the introduction of Internet service providers; the first commercial provider was The World, based in Massachusetts, in November 1989. In the relatively short time since the conception of this efficient communication network, it has been the most instrumental tool in transforming our world and the way we live today. The invention of the personal computer expanded our personal capabilities, but the concept of the packet-switching network facilitated our transformation into a worldwide, interconnected species capable of rapid information sharing to effect immediate attention or action as needed.

Zachary Green

See also ARPANET; Vol. 3, Sec. 2: Internet; Personal Computer (PC)

Further Reading

Baran, Paul. 1964. "On Distributed Communications: I Introduction to Distributed Communications Network." RAND Memorandum RM-3420-PR.

Davies, D. W., K. A. Bartlett, R. A. Scantlebury, and P. T. Wilkinson. 1967. "A Digital Communications Network for Computers Giving Rapid Response

at Remote Terminals.” ACM Symposium on Operating Systems Principles. October.

Kleinrock, Leonard. 1961. “Information Flow in Large Communication Nets.” Proposal for a PhD Thesis, Massachusetts Institute of Technology.

Particle Accelerator

Particle accelerators are machines that propel charged particles to very high speeds using electromagnetic fields. Researchers can collide two beams of accelerated particles in order to study the resulting matter and the forces involved. It is presumed that conditions in modern high-energy particle accelerators reproduce conditions similar to those at the birth of our universe—the Big Bang—giving us a window into how it was created in the first place.

Particle accelerators are a product of the 20th century. Until then, scientists could theorize and try to prove hypotheses with mathematics, but advancements couldn’t be made unless theories could actually be tested. Particle accelerators have opened the door to our modern-day understanding of the building blocks that turn energy into matter.

There are two types of particle accelerators: linear and circular. Both use electromagnetic waves to speed up atomic particles, and the more energetic a particle can be made, the better researchers can determine the structure of its matter. Linear accelerators push a beam of particles down a long vacuum toward a target at the end of a tube, where detectors record the results. Circular accelerators push particles around in a circle, gaining energy with each pass until they hit their intended target and an array of detectors records the results. The first circular particle accelerator was created in 1930 at the University of California, Berkeley by Ernest Lawrence and M. Stanley Livingston and accelerated hydrogen ions within a chamber less than five inches in diameter.

All particle accelerators are made of the same basic components. There is a particle source that provides the particles to be accelerated; a copper tube in which the particle beam travels through a vacuum; a klystron, a microwave generator that makes the waves that the particles ride on; electromagnets to steer and

confine particles to a tight beam; targets, the particle collision points; detectors, which measure pieces and radiation created by the collision; vacuum systems that remove all particles from the tube; cooling systems to remove heat produced by the magnets; a computer that controls accelerator operations and analyzes data; shielding to protect anyone nearby from the radiation produced; monitoring systems used to see inside and measure radiation to determine what happened in the accelerator; an electrical power system to provide electricity; and storage rings to temporarily store beams not being used.

When scientists first started using particle accelerators, they discovered hundreds of particles smaller than the three well-known subatomic particles: protons, neutrons, and electrons. They also recognized the correlation between the amount of energy put into the accelerator and the number of particles they could detect. As scientists began to classify and organize these particles, a standard model of the atom became clear. The model outlined the ability to group matter into the following categories: fermions, which make up matter and antimatter; leptons, elementary particles like electrons and neutrinos; quarks, basic particles that hold the nucleus together; antimatter, opposite particles to quarks and leptons; hadrons, composite particles like protons and neutrons; and bosons, particles that carry force and help to give energy mass.

The array of subatomic particles that result from particle accelerator collisions are also thought to control the four fundamental forces: the strong force, which holds the nucleus of the atom together; the weak force, which is involved in radioactive decay; electromagnetism, which controls interactions between charged particles; and gravity, which acts as an attractive force based on mass and distance. Experiments in particle accelerators have shown us that under the right conditions, the electromagnetic force and the weak force can combine to become the “electroweak” force, leading other scientists to believe that the different forces may have stemmed from one unified force that existed long ago.

Much of our understanding of particle physics is all thanks to the largest, most expensive, and most complex experiment ever constructed in human history: the Large Hadron Collider at CERN in Geneva,

Switzerland. This is a circular underground structure with a circumference of 27 kilometers (17 miles), and at a depth ranging from 50 to 175 meters (164 to 574 feet) underground. The total operating budget of the LHC runs about \$1 billion per year, and all costs considering, the total cost of finding the Higgs boson ran about \$13.25 billion. This machine alone can be credited for expanding our understanding of the workings of the universe to the limits that we currently hold.

In the United States, the Relativistic Heavy Ion Collider (RHIC) was installed in Brookhaven National Laboratory on Long Island, New York, in 1994. Particle accelerators have become part of popular culture as an icon of our modern world and a testament to our quest to understand the universe around us. But most people don't know just how many particle accelerators there are in the world.

With tens of thousands of particle accelerators in use across the planet, most people do not understand the major role these machines play in our everyday lives. Although they are best known for particle physics research, particle accelerators also help us to create cancer-destroying beams, kill bacteria to prevent food-borne illnesses, improve jet fuel, develop shrink wrap

and diapers, develop semiconductors, clean the air, diagnose medical conditions, and produce powerful x-rays for medical research. They help DNA researchers to analyze and define how the ribosome translates DNA into life. Particle accelerators have profoundly expanded our knowledge and have been crucial in improving human lives.

Zachary Green

See also Jet Propulsion Laboratory (JPL); Satellites and Space Probes; *Vol. 3, Sec. 3: Cancer Research*

Further Reading

Freudenrich, Craig. 2001. "How Atom Smashers Work." Science/Nuclear Science. February. Howstuffworks.com. <https://science.howstuffworks.com/atom10.htm>, accessed September 25, 2018.

Knapp, Alex. 2012. "How Much Does It Cost to Find a Higgs Boson?" *Forbes*. July.

Zeldovich, Lina. 2014. "10 Reasons Why You Can't Live without a Particle Accelerator." *Nautilus*. June 12. <http://nautil.us/issue/14/mutation/10-reasons-why-you-cant-live-without-a-particle-accelerator>, accessed August 31, 2018.

Primary Document: Press Release Issued by CERN, the European Organization for Nuclear Research (2012)

As of today, the leading ideas in particle physics are based around a scientific proposal called the Standard Model. One of the leading academics behind this understanding is Peter Higgs, who, with his colleagues, predicted the existence of a specific subatomic particle that causes other subatomic particles to come together and form atoms, essentially giving mass to the universe. On July 4, 2012, at the Large Hadron Collider in Geneva, Switzerland, scientists received data from the largest and most expensive experiment in human history. The data gave concrete proof that detected the existence of this particle, lending credence to the accuracy of the Standard Model. For Higgs's revolutionary ideas, he was awarded the Nobel Prize in Physics on October 8, 2013. This press release announcing the event came

from CERN, the European Organization for Nuclear Research.

CERN experiments observe particle consistent with long-sought Higgs boson
4 Jul 2012

Geneva, 4 July 2012. At a seminar held at CERN today as a curtain raiser to the year's major particle physics conference, ICHEP2012 in Melbourne, the ATLAS and CMS experiments presented their latest preliminary results in the search for the long sought Higgs particle. Both experiments observe a new particle in the mass region around 125-126 GeV.

"We observe in our data clear signs of a new particle, at the level of 5 sigma, in the mass region around 126 GeV. The outstanding performance of the

LHC and ATLAS and the huge efforts of many people have brought us to this exciting stage,” said ATLAS experiment spokesperson Fabiola Gianotti, “but a little more time is needed to prepare these results for publication.”

“The results are preliminary but the 5 sigma signal at around 125 GeV we’re seeing is dramatic. This is indeed a new particle. We know it must be a boson and it’s the heaviest boson ever found,” said CMS experiment spokesperson Joe Incandela. “The implications are very significant and it is precisely for this reason that we must be extremely diligent in all of our studies and cross-checks.”

“It’s hard not to get excited by these results,” said CERN Research Director Sergio Bertolucci. “We stated last year that in 2012 we would either find a new Higgs-like particle or exclude the existence of the Standard Model Higgs. With all the necessary caution, it looks to me that we are at a branching point: the observation of this new particle indicates the path for the future towards a more detailed understanding of what we’re seeing in the data.”

The results presented today are labelled preliminary. They are based on data collected in 2011 and 2012, with the 2012 data still under analysis. Publication of the analyses shown today is expected around the end of July. A more complete picture of today’s observations will emerge later this year after the LHC provides the experiments with more data.

The next step will be to determine the precise nature of the particle and its significance for our understanding of the universe. Are its properties as expected for the long-sought Higgs boson, the final missing ingredient in the Standard Model of particle physics? Or is it something more exotic? The Standard Model describes the fundamental particles from which we, and every visible thing in the universe, are

made, and the forces acting between them. All the matter that we can see, however, appears to be no more than about 4% of the total. A more exotic version of the Higgs particle could be a bridge to understanding the 96% of the universe that remains obscure.

“We have reached a milestone in our understanding of nature,” said CERN Director General Rolf Heuer. “The discovery of a particle consistent with the Higgs boson opens the way to more detailed studies, requiring larger statistics, which will pin down the new particle’s properties, and is likely to shed light on other mysteries of our universe.”

Positive identification of the new particle’s characteristics will take considerable time and data. But whatever form the Higgs particle takes, our knowledge of the fundamental structure of matter is about to take a major step forward.

Footnote(s)

1. CERN, the European Organization for Nuclear Research, is the world’s leading laboratory for particle physics. It has its headquarters in Geneva. At present, its Member States are Austria, Belgium, Bulgaria, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Italy, the Netherlands, Norway, Poland, Portugal, Slovakia, Spain, Sweden, Switzerland and the United Kingdom. Romania is a candidate for accession. Israel is an Associate Member in the pre-stage to Membership. India, Japan, the Russian Federation, the United States of America, Turkey, the European Commission and UNESCO have Observer status.

Source: Amaldi, Ugo, and Geoffrey Hall. 2015. *Particle Accelerators: From Big Bang Physics to Hadron Therapy*. New York: Springer.

Pauling, Linus “Carl” (1901–1994)

A Nobel Prize-winning chemist and peace activist, Linus “Carl” Pauling was also a biochemist and an educator who published over 850 science-related books and helped found the fields of quantum chemistry and molecular biology. Born on February 28, 1901, in Portland,

Oregon, Pauling had one sister. Amazed at what combining different substances could do, the young man developed a passion for chemistry. He later quit a job as a machinist to pursue a university education.

Despite his parents’ belief that his current occupation was sufficient, the 16-year-old Pauling applied to Oregon Agricultural College in Corvallis, Oregon,

where he received his bachelor's in chemical engineering in 1922 while also working full time at a variety of jobs to pay his own tuition, since his parents would not. He then pursued a PhD at the California Institute of Technology (Caltech) in chemistry and mathematical physics, which he earned in 1925, just three years after his first degree.

A year later, he earned a Guggenheim Fellowship that allowed him to spend two years studying under a series of European physicists focused on quantum mechanics. When he returned to the States, Caltech hired him to teach theoretical chemistry. Four years later, the American Chemical Society granted him their Langmuir Prize celebrating significant work in pure science done by a chemist under the age of 30.

A friendship with fellow professor Robert Oppenheimer soured after Oppenheimer flirted openly with Ava Helen Miller, the human rights activist who had married him in 1923. The marriage lasted; the friendship with Oppenheimer did not.

In 1932, Pauling created the Pauling Electronegativity Scale, which predicts the nature of bonds between atoms in molecules and is still in use today. Likewise, he created the concept of orbital hybridization, which described different ways that electrons in molecules bond.

Despite their estrangement, at the start of the Manhattan Project during World War II, Oppenheimer invited Pauling to join the team to lead the chemistry division, but Pauling declined in favor of working for the military on a broader series of projects. For them, he invented the Pauling oxygen meter to measure oxygen conditions in submarines and airplanes. At the same time, due to his wife's influence, Pauling joined the Emergency Committee of Atomic Scientists created and chaired by Albert Einstein to warn the public of the dangers associated with the development of nuclear weapons. For this and other contributions to safety for soldiers, Pauling was awarded a Presidential Medal for Merit by President Harry S. Truman in October 1948.

Based on the completion of his groundbreaking textbook *The Nature of the Chemical Bond*, Pauling received the Nobel Prize in Chemistry in 1954. But his attention after the war turned to advocating for peace. He wrote a stream of letters to politicians and other people of influence voicing concern over the use of

nuclear weapons and promoting nuclear disarmament. He also published books on the subject of peace and participated in debates around the country. The work that Pauling, Miller, and their fellow peace advocates did resulted in John F. Kennedy and Nikita Khrushchev signing the Partial Test Ban Treaty of 1963. That year, the Nobel Prize Committee awarded Pauling the Nobel Peace Prize for 1962.

Not only was Linus Pauling an accomplished scientist and a peace activist, he was a husband and a father. Pauling and Miller had four children who all grew up to be involved in the sciences, from psychiatry to biology and geology. Pauling passed away August 19, 1994, from prostate cancer.

Rosanne Welch

See also Vol. 2, Sec. 3: Atomic Bombs/Nuclear Weapons

Further Reading

Mead, Clifford. 2008. *Linus Pauling: Scientist and Peacemaker*. Corvallis: Oregon State University Press.

Mian, Zia. "Out of the Nuclear Shadow: Scientists and the Struggle against the Bomb." *Bulletin of the Atomic Scientists*, vol. 71, no. 1 (Jan. 2015): 59–69. doi:10.1177/0096340214563680.

Permanent Press Fabric

Winner of the Lifetime Achievement Award, Ruth Benerito is credited with saving the cotton industry through her invention of permanent press fabric while working for the U.S. Department of Agriculture in the 1950s. Ruth Benerito was a prolific chemist and inventor who was granted a total of 55 patents. She was awarded membership in the National Inventors Hall of Fame for her contributions to science and education. In the early years of her career, she invented permanent press cotton by attaching organic chemicals to cotton fibers. Her patented process helped start a revolution in the fabrics industry.

Benerito was born Ruth Mary Rogan on January 12, 1916, in New Orleans, Louisiana, to Bernadette and John Edward Rogan, who both advocated for

women's liberation. Benerito graduated from high school in New Orleans at the age of 14 and enrolled in H. Sophie Newcomb Memorial College at Tulane University at the age of 15. She received her bachelor's degree in chemistry in 1935, during the Great Depression. Due to the scarcity of employment, she took a position at Jefferson Parish High School as a teacher of math, science, and driver's education while also attending night classes at Tulane until receiving her master's degree in physics in 1938.

Benerito then taught college classes at Tulane University while using summer and other school leaves to complete her doctorate in physical chemistry from the University of Chicago in 1948. She married Frank Benerito in 1950 and soon after went to work at the U.S. Department of Agriculture's Southern Regional Research Laboratories in New Orleans. Benerito worked at the USDA for most of her career and was granted a total of 55 patents, the most notable of which was her process for creating permanent press cotton fabric, and the creation of stain- and fire-resistant fabrics has been attributed to her as well. Her husband, Frank, died 20 years after they married.

With the 1930s and 1940s inventions of nylon and polyester, fibers that did not need pressing, the cotton industry suffered a catastrophic blow that left it in rapid decline. In the 1950s, Benerito's research team at the USDA identified the fragility of the hydrogen bonds in cotton that led cotton fabrics to wrinkle easily. Benerito and her team overcame the issue by treating the fibers with formaldehyde and other organic chemicals to replace the weak hydrogen bonds with a synthetic "cross-linking." This process was later refined by Benerito and others to be more environmentally friendly and more user-friendly. Cotton saw a resurgence in fashion by the 1990s.

Benerito dedicated the majority of her life to teaching until retiring in 1997. She died in 2013 at age 97.

Zachary Green

See also Sherman, Patsy O'Connell

Further Reading

Benerito, R. R., J. B. McKelvey, and R. J. Berni. 1966. "A New Theory of Resiliency in Cotton." *Textile Research Journal* 36: 251–64.

Langer, Emily. 2013. "Ruth Benerito, Agriculture Dept. Chemist Who Made Cotton Wrinkle-Free, Dies at 97." *The Washington Post*, October.

Sway, Rachel. 2017. *Trailblazers: 33 Women in Science Who Changed the World*. New York: Random House.

Petroleum Industry (Post–World War II)

Despite significant resources in states like California and Texas, following the end of World War II, the United States became increasingly dependent on oil from foreign sources. The vast scale of industrial production in the United States, combined with the affordability of the automobile for huge numbers of American consumers, meant that American demand for oil was progressively outpacing current domestic supply, and other nations, like Mexico and Venezuela, could produce oil more cheaply. U.S. oil companies operated in the Middle East with the agreement of host nations, reaping enormous profits, and the U.S. government worked to secure foreign oil supplies.

In 1953, the United States (along with Britain) covertly overthrew Prime Minister Mohammad Mossadegh of Iran due to fears that Mossadegh was moving the country (and its vast oil holdings) toward support of the Soviet Union. By the end of the decade, small domestic producers were increasingly unable to compete with large multinationals operating in foreign countries. The Eisenhower administration instituted quotas on imported oil to protect small producers (though the United States was still largely dependent on foreign oil for a large percentage of its oil use). The quotas infuriated oil-producing nations throughout the next decade.

The U.S. dependence on foreign oil came into visceral focus for Americans in the 1970s. In October 1973, when the United States was discovered to be providing covert support to Israel in the Yom Kippur War against Egypt, the oil-producing countries of the Middle East instituted a graduated cutback of oil exports to the United States as punishment. Long lines appeared at gasoline stations across the country, with irate drivers getting into shouting matches and even fistfights with each other as they waited (sometimes

for hours) to buy the gasoline essential to completing their daily routines. President Richard Nixon instituted price controls on oil produced domestically to try to keep gasoline prices down, but he could do little about the price of imported oil, which rose steadily throughout the fall. Because American oil companies drilling in the Middle East split profits with the host governments, the retaliatory price increases caused American oil companies operating in the Middle East to see their profits balloon. The American public became enraged upon hearing that oil companies had reaped massive profits while consumers suffered.

The embargo caused redoubled efforts to increase domestic oil production. In the late 1960s, the oil company Atlantic Richfield had confirmed the existence of a significant oil field in the Prudhoe Bay area on Alaska's North Slope. Yet the emerging environmentalism of these years, combined with a general distrust of large institutions after the Vietnam War and Watergate, made it difficult to muster the political will to build the 800-mile-long pipeline to bring the oil to the southern coast. (The northern waters contained too many icebergs to send tankers directly to the oil field.) It was only after the embargo and the resulting anxieties about energy security that the pipeline was approved in Congress, and it passed by the slimmest of margins, with Vice President Spiro Agnew breaking a tie in the Senate.

Five major oil companies agreed to share construction costs and ownership, but the pipeline itself represented a massive engineering project. Long sections of the pipeline were set high above the ground, as the natural heat exuded by crude oil would melt the Alaskan permafrost. But other sections had to be buried so as not to disturb caribou migration routes, which necessitated heavy insulation. The pipe was built in a zigzag pattern to absorb the shrinking and expanding caused by the heat of the oil, and extreme zigzags were added in the Denali area to compensate for potential seismic activity. Though the pipeline has been safely transporting crude oil across Alaska for decades, the 1989 *Exxon Valdez* oil spill in Prince William Sound damaged its environmental legacy.

After the end of the 1973 oil crisis caused immediate fears to dissipate, American consumption patterns quickly returned to normal. Jimmy Carter, a former nuclear engineer elected to the presidency in 1976,

attempted to encourage conservation to achieve a lasting reduction in aggregate energy consumption. However, Americans who had become accustomed to large cars and comfortable daily routines resisted admonitions to change their way of life, demanding that the government solve the problem instead. And in late 1978, protests against Iran's ruling shah paralyzed the country, forced the evacuation of Western expatriates working in Iran's oil industry, and caused world oil prices to spike again. Revolutionary Iranians believed that the shah was exporting the nation's oil wealth to the West, and they replaced him with the religious fundamentalist Ayatollah Khomeini.

Carter's response to this second energy crisis took multiple forms. First, he created the Synthetic Fuels Corporation in 1980, which provided federal subsidies to oil and gas companies for commercial production of synthetic fuel (liquid fuel obtained through chemical reactions from sources such as coal). Carter also moved to eliminate the price controls on domestic crude oil that had been instituted earlier in the 1970s. Raising the price, he thought, would force Americans to use less oil and embrace conservation and alternative sources instead. But Carter was worried that oil companies would use the increased profits resulting from decontrol to buy hotels and department stores, and so, alongside decontrol, he instituted a "windfall profits" tax to reinvest oil revenues into alternative energy research.

Oil companies strongly supported decontrol but opposed the tax on increased revenues. High-ranking oil executives testified in Congress that the tax would inflict immense damage to the industry. Pointing to the complex challenges presented by the Alaska pipeline's construction, they argued that future domestic discoveries would almost certainly be found in similarly remote and inhospitable places (such as the ocean floor) and would require vastly greater investment in exploration and construction than had the easy discoveries of past decades. Carter rejected the industry's argument and instituted the tax, though his successor Ronald Reagan repealed it soon after taking office in 1981. The uncertainty caused by the multiple oil crises in the 1970s helped decrease American demand for oil, which led global prices to drop in the early 1980s, and the Synthetic Fuels Corporation was abolished in 1985 on the grounds that it was no longer needed.

The latter years of the 20th century (and the first of the 21st) witnessed mergers in the oil industry that created some of the most valuable companies in the world. In 1984, Standard Oil of California merged with Gulf Oil (the largest merger in history at that point) to create Chevron. Chevron acquired Texaco in 2000 and the Unocal Corporation in 2005. In 1999, Exxon and Mobil merged to create ExxonMobil, which in 2014 was the third-largest company in the world. The second-largest, the Anglo-Dutch oil company Shell, trailed only Walmart.

The petroleum industry's environmental impact, which had been criticized in 1969 with an oil spill off the coast of Santa Barbara and again in 1989 with the *Exxon Valdez* spill, came under even more intense scrutiny in April 2010. An offshore oil rig in the Gulf of Mexico experienced a blowout when high-pressure methane gas from the underwater well rose into the drilling rig, where it ignited and exploded. Oil gushed from the damaged well, and the equivalent of over 4 billion barrels of oil were released into the Gulf. The spill caused significant damage to the shrimping and tourism industries on the Gulf Coast and generated intense criticism from the U.S. government and the press.

Another major environmental controversy had to do with the proposed Keystone XL pipeline. The XL portion was a prospective addition to an existing system that already carried oil from Alberta to the Gulf Coast, but the XL project would run over delicate sand dunes in Nebraska as well as the Ogallala Aquifer, a major source of drinking water. In early 2012, President Barack Obama rejected the XL proposal, citing environmental concerns. Although Nebraska's governor approved a revised plan in early 2013 designed to minimize impact on the dunes and aquifer, the Obama administration announced an indefinite extension of the federal review process in the spring of 2014. Because the decision came alongside strict new rules on carbon emissions, the administration's decision was likely based not on the pipeline's physical impact on the land but on broader concerns about the long-term environmental sustainability of fossil fuel use.

The 21st century also brought an oil boom to the state of North Dakota, which sits atop a rock formation known as the Bakken, which is composed of sedimentary rock from which oil can be produced. Oil was first

discovered within the Bakken formation as early in 1951, but for decades the cost of retrieving it from the ground was prohibitive. Two technologies made harvesting the shale oil cost-effective by 2000: hydraulic fracturing (injecting high-pressure liquid into a well-bore to create small cracks and allow the petroleum to move to the well) and slant drilling (which allows oil wells to be drilled at nonvertical angles. Despite the nationwide economic crisis that began in 2008, North Dakota experienced an economic explosion, with developers unable to keep up with the housing needs of the massive inflow of workers and the government unable to build enough schools for their children.

William Michael Camp

See also Automotive Technologies (Post–World War II); *Vol. 2, Sec. 2: Automobile Technologies (Pre–World War II)*; *Vol. 2, Sec. 3: Interstate Highway System*

Further Reading

- Coates, Peter A. 1991. *The Trans-Alaska Pipeline Controversy: Technology, Conservation, and the Frontier*. Fairbanks: University of Alaska Press.
- Vietor, Richard H. K. 1984. *Energy Policy in America since 1945: A Study of Business-Government Relations*. Cambridge: Cambridge University Press.
- Yergin, Daniel. 1991. *The Prize: The Epic Quest for Oil, Money, and Power*. New York: Simon & Schuster.

Plasma Arc Welding

Plasma arc welding (PAW) is an advanced welding system that allows the welder the accuracy necessary to weld both thin and thick metals. This precision results in more advanced welding capabilities and techniques. Welding precision, along with PAW's reliability, have revolutionized the welding industry ever since the system hit the market.

Robert M. Gage introduced plasma arc welding in 1954 and ultimately patented his invention in 1957. However, it was not until 1964 that Gage's welding device was brought to the market. PAW uses plasma gas, which is an ionized gas and considered to be a fourth state of matter because of its unique capabilities. PAW is similar to gas tungsten arc welding; however,

in plasma arc welding, the plasma is forced through a copper nozzle, which results in the gas coming out at a much higher temperature compared to gas tungsten arc welding. During welds, the arc in the welding system can reach temperatures up to 33,000°C. The PAW system includes a plasma torch, voltage control, current control, high-frequency generator, and shielding gases.

During the welding process, the system uses plasma gas to transfer an electric arc to the metals being worked on. Because of the heat of the arc, the metals being welded bind and fuse together. The PAW system transfers an intense heat to a small, concentrated area, leading to more accurate welds.

When working with plasma arc welding, weld times can be as short as five milliseconds, and the system is even stable at low amps. Additionally, PAW sports a protected electrode, which allows for less contamination and results in cleaner welds. The system's versatility allows it to be used for welding anything from kitchen appliances and surgical instruments to jet engine blades and automobile chassis. Also, due to PAW's long electrode life, the system can be used in high production situations. Plasma arc welding can also be used in cutting applications. During plasma cutting, the plasma gas needs to be increased so it can result in deeper penetration of the metal being cut.

Today, plasma arc welding is still one of the most popular welding systems. Over the years, the PAW system has received minor but significant improvements. The modern system is still a favorite among welders, and it is used across various industries.

Arno Aghababian

See also CO₂ Welding

Further Reading

- Liu, Zu Ming, ShuangLin Cui, Zhen Luo, ChangZhen Zhang, ZhengMing Wang, and YuChen Zhang. 2016. "Plasma Arc Welding: Process Variants and Its Recent Developments of Sensing, Controlling and Modeling." *Journal of Manufacturing Processes* 23: 315.
- Wu, C. S, L. Wang, W. J. Ren, and X. Y. Zhang. 2014. "Plasma Arc Welding: Process, Sensing, Control and Modeling." *Journal of Manufacturing Processes* 16, no. 1: 74.

Plastics

Plastics are a subset of polymer materials and have a wide range of composition from organic to fully synthetic compounds. Plastic is known for its light weight, high malleability, and high moldability. Malleability is a material's ability to deform under stress without fracturing, thus allowing plastic to be hammered or rolled into thin sheets. Synthetic plastics are commonly derived from petroleum, while semisynthetic or nonsynthetic plastics can derive from cellulose. Due to the low cost of production, ease of manufacture, low density, high toughness, versatility, and other desirable properties, plastics have extensive range of and uses and have displaced a great variety of materials that we used to make products from such as wood, metal, and glass.

Plastics can be separated into two categories based on their chemical composition. Carbon-chain plastics are made of linear hydrocarbon polymer. Polyethylene, PVC, polystyrene (Styrofoam), and PTFE are examples of carbon-chain plastics. The second category, heterochain polymers, consist of not just carbon atoms but oxygen, nitrogen, sulfur, or even aromatic rings in their chains. PET, polyurethane, epoxies, polyester, and nylon are examples of heterochain plastics. Each type of plastic has specific properties, such as density, tensile strength, melting temperature, etc., that need to be considered for its intended application. Plastic have been called "the material of a thousand uses," and they certainly have revolutionized the way the world produces and consumes various products.

Plastics evolved out of the use of rubber made from natural materials such as natural gums, latex rubber, and shellac. However, these rubber products often cannot withstand extreme temperatures. In hot environments, they would become intolerably sticky and tacky to touch. In cold environments, they would become too hard and brittle to work well. The unwanted properties of rubber kept industrial interest in it at bay until a method of curing it was possible.

Charles Macintosh, a frugal Scottish dye maker, found himself with too much naphtha after separating ammonia from tar. In an effort to do something with the naphtha, he immersed some raw rubber in it. To his

pleasure, he had obtained a liquid rubber solution that could be brushed on cloth. In 1821, he started coating canvas with this rubber solution to make a waterproof raincoat called a “mack.”

In the United States, Charles Goodyear was long fascinated with the special properties of rubber and was determined to improve it. Goodyear’s relentless efforts often drove him to bankruptcy and debt. His first moderate success was in treating rubber with nitric acid vapors laced with sulfuric acid, which dramatically improved rubber’s heat resistance on the outside. In 1839, he had a stroke of luck. While working with latex mixed with sulfur, he dropped some on a hot stove. Rather than melting into a goo as any ordinary rubber would, this mixture charred evenly, ending up like a piece of leather. After it was cool enough to scrape off, the new material stayed pliable, even in the winter cold.

Goodyear eventually perfected his new processing method but raised only enough funding to file for an American patent and not a British one. He appointed a young Englishman, Stephen Moulton, to meet with Thomas Hancock and Charles Macintosh in hopes of a joint venture and a British patent. Hancock, seeing the possibility, spent weeks in his lab to tackle the problem himself and came to the conclusion that sulfur was indeed the key. He filed for a British patent just two months before Goodyear did and coined the name for the process: “vulcanization.”

In 1846, a British surgeon practicing in Madagascar noticed a shiny, dark brown material that the natives were selling called “gutta-percha.” Gutta-percha was softened in hot water, pressed by hand, and became rock hard after cooling. Recently expanded international telegraphy lines lacked sufficient insulation to coat submarine telegraph lines, as rubber was not corrosive resistant enough in salt water. Gutta-percha, on the other hand, was resistant to salt and electrical current.

In 1862, Alexander Parkes, an English inventor, made the first man-made organically derived plastic, nitrocellulose. It was made by treating cellulose with nitric acid and a large quantity of castor oil. However, the plastic was not malleable, and the amount and cost of castor oil required was too high for Parkes’s company. Investors decided to pull out. In 1868, American

John Wesley Hyatt improved on Parkes’s nitrocellulose by treating it with camphor instead of castor oil, which did make it malleable. The new plastic could even imitate ivory and tortoiseshell. Hyatt called this improved plastic “celluloid,” and it became the first commercially successful plastic, but it did have a flaw. Camphor is quite flammable, and subsequently it burned a four-story celluloid plant down in just under two hours.

It was not until 1907 that a big breakthrough set the precedent for the first synthetic plastic. Having had much success in 1899 making and selling the new photographic paper called “Velox,” which made developing photographs quick and easy at home, an American immigrant chemist named Dr. Leo Baekeland set his eyes on making viable synthetic resin. Baekeland began investigating the reaction of phenol and formaldehyde and approached the issue systematically, considering temperature, pressure, material, and proportion. After years of research, he found a way to produce a hard, moldable plastic that he called “Bakelite,” and he finally introduced the material to the world in 1909. It took several years—until the 1920s—for the world to fully accept the concept of polymers. But as early as 1927, publicists had proclaimed the Plastic Age of historical significance equal to that of the Bronze, Iron, or Steel Ages.

Plastic had become such an integral part of the world by the 1920s that Baekeland proudly claimed that he could name no more than 43 industries that had no use for his Bakelite at all. By World War II, the plastic industry had expanded so much that baby boomers grew up with them as a major component of their lives and in everything from toys to grocery bags. In the United States, production tripled from 1940 to 1945, and in 1945, 818 million pounds were produced. Most of those plastics went to military uses. New materials and processes were constantly being tested as well. Vinyl polymers were in experimental use, transparent acrylic was a promising alternative as unbreakable “glass,” and the injection-molding process made production cheaper and faster. By 1960, annual production surpassed 6 billion pounds and, 50 years later in 2011, annual production exceeded 600 billion pounds.

In the past, metal, glass, rags, leather, and other materials that we made things from could be scrapped and resold to industry as informal recycling. What could not be used or sold was burned as a source of heat. There was little waste as we think of it today. As early as the 1920s, it became common to throw garbage into landfills. Although packaging required the increasing consumption of plastic, plastic was everlasting and reusable. But the low cost and speed of production made it “disposable.” In the late 1960s and early 1970s, critics warned that disposing of synthetic materials in landfills was an environmental disaster, as they did not degrade quickly. By the 1980s, major U.S. cities began establishing plastic and recyclable collection programs, with Rhode Island becoming the first state to mandate recycling in 1986. In 2011, about 70 percent of plastic scraps in the U.S. were shipped to China for recycling at an estimated worth of \$11.3 billion.

With ever-growing concern for the environment, there has been a push toward plastic that is environmentally friendly, like bioplastic. Currently, there are three main groups of bioplastic. One is bio based and biodegradable, such as polylactic acid and polyhydroxyalkonate, which are derived from natural and renewable resources. Another group of bioplastic that is partially or fully bio based but not biodegradable, such as bio-polyethylene or bio-polyethylene terephthalate (PET) is derived from renewable resources. Last but not least are bioplastics that are fossil fuel based and biodegradable, such as polybutyrate. The move toward bioplastic is to reduce the reliance on nonrenewable resources, but currently, bioplastic is more costly to manufacture, and not all bioplastic can be recycled through conventional methods—or it requires a specific composting process.

Allen Kuo

See also *Vol. 1, Sec. 3*: Goodyear, Charles

Further Reading

- Fenichell, Stephen. 1996. *Plastic: The Making of a Synthetic Century*. New York: HarperCollins.
- Meikle, Jeffrey L. 1995. *American Plastic: A Cultural History*. New Brunswick, NJ: Rutgers University Press.

Polaroids

In 1948, Edwin Land invented the Polaroid camera and revolutionized photography, allowing photos to be seen shortly after they were taken.

After graduating from Harvard, Land founded the Polaroid Company in 1937, locating the facility near Harvard and MIT to attract top talent. A team of 37 joined his initial project of adding polarizers to auto headlights to reduce the glare of oncoming traffic. Although many car companies expressed interest in this new feature, they were reluctant to invest. The rejection almost caused the company to fail.

World War II helped Polaroid recover quickly, and it shifted production to support the war effort. The company helped develop planes capable of taking aerial photographs and then putting those photos onto a special film with polarizing dyes for better resolution. War work left the company flush with government funds for more diverse research, including film research.

On a family vacation in 1944, Land took a photo of his daughter, who asked why she couldn't see the picture right away. He couldn't provide a reasonable explanation for why that wasn't possible. Thus, when he returned to work, he assembled a team to find a way to make photos appear instantly. In 1946, the company created a silver-image (black-and-white) photograph. A photo appeared moments after capture, shrouded with a negative layer that had to be removed to reveal the image. However, the development process proved difficult, creating unstable photos often accompanied by chemical residue. After enlisting the help of chemists to correct image issues, the first instant Polaroid camera became available for purchase in November 1948. The camera was large and cumbersome, and the first photos were often yellow or brown and unappealing. However, Land had achieved his goal of creating instant photography.

Building on that success, he now wanted to develop instant color photos. To assist in the project, Edwin Land partnered with Kodak. The companies agreed that Polaroid would complete the chemical and process research and Kodak would supply the necessary emulsions to

produce color photographs. In 1963, they succeeded, and Polaroid color film became widely sold, an instant success.

Always striving to improve his product, Land set out to make the Polaroid experience most recognized today: a camera capable of producing a color photo instantly, without the need to remove any layers. That camera was the SX-70, appearing first in 1972. SX-70s sold rapidly, and by 1973, about 5,000 cameras were manufactured and sold daily.

Despite the achievements and the dedication to innovation of Land and Polaroid, the success of the camera was short-lived, peaking in the 1970s and decreasing during the 1980s and 1990s. Technological advancement and the introduction of digital and cell-phone cameras diminished the phenomenon of the Polaroid. To adapt, Polaroid continues to create updated versions of the Polaroid camera sold at many large retailers, connecting past to present and securing Polaroid's place in the technological world.

Rebecca Morello

See also *Vol. 1, Sec. 3: Military Technology (Civil War); Vol. 2, Sec. 3: Photocopier*

Further Reading

Blout, E. 1996. "Polaroid: Dreams to Reality." *Daedalus* 125, no. 2: 39–53.

Bonanos, C. 2012. *Instant: The Story of Polaroids*. New York: Princeton Architectural Press.

Polio Vaccine

Polio vaccines were developed in the 1950s to resist poliomyelitis (or, commonly, "polio") by means of immunization and preventative medicine. Polio reached pandemic proportions in the first half of the 20th century, and the campaign to discover and propagate the vaccine was seen as one of the triumphs of modern American medicine. The application of these vaccines has nearly eradicated the disease and dramatically lowered its presence globally. The polio vaccine remains on the World Health Organization's List of Essential Medicines, which outlines medical items necessary for establishing the most basic standard for medical care worldwide.

Polio is an infectious disease that causes muscle weakness and paralysis. It most commonly affects leg muscles but can affect the arms, torso, and neck as well. The adult mortality rate for polio is upward of 30 percent, while for children it is 2 to 5 percent. Some polio sufferers recover entirely, while others suffer from muscle weakness and paralysis for the rest of their lives. The polio virus is spread through fecal matter ingestion, making the disease particularly problematic in developing nations. The polio vaccine is effective at stopping the disease, though currently the Centers for Disease Control recommends that persons who have been vaccinated get a booster shot before traveling to countries experiencing polio outbreaks.

The first clinical assessment of polio dates to 1789 and was composed by the English physician Michael Underwood. However, polio as a viral disease can present a wide range of symptoms (or indeed, no symptoms at all) and has existed since the earliest recorded civilizations. The minority of cases (somewhere around 1 to 2 percent) result in the virus entering the nervous system and spinal cord, causing paralysis and physical deformity.

Such a variety of symptoms and victims meant that polio was difficult to discretely diagnose, and it wasn't until the late 19th century that the combined efforts of German physician Jakob Heine and Swedish pediatrician Karl Oscar Medin led to the identification of polio as Heine-Medin disease, or "infantile paralysis." During the 20th century, the incidence of polio shifted from infants to children and young adults, whose age group as a whole had a greater chance of paralysis from the virus. In 1952 and 1953, the United States witnessed a surge of polio cases at nearly twice the yearly average. Such alarming numbers prompted public organizations and private laboratories such as Lederle Laboratories in New York and the University of Michigan Poliomyelitis Vaccine Evaluation Center to seek out a preventative vaccine.

A number of early experiments to create a polio vaccine failed to achieve positive results. In 1936, Maurice Brodie attempted to fashion a vaccine from attenuated (reduced in virulence) polio retrieved from the spinal cords of experimental monkeys. He administered this vaccine to several thousand children without conclusive results. A later experiment by pathologist

John Komer in Philadelphia was later blamed for some children contracting the disease. In 1948, John Enders successfully grew polio virus from human tissue in laboratory conditions. Such developments in replicating polio furthered vaccine research by providing a thorough understanding of the workings of the virus and its development within the human body.

The first polio vaccine was developed in 1952 by Jonas Salk, an American virologist and physician working at the University of Pittsburgh. Salk's vaccine was derived from three strains of polio raised in the kidney tissue of a monkey and rendered innocuous with formalin, a variety of formaldehyde. With the pitfalls of the previous attempts at a polio vaccine in mind, Salk and his collaborators submitted his vaccine to a long period of clinical trial and testing. Salk's test runs on children started in 1953 and were heavily advertised in print media and broadcast on radio as a public relations tool. At its height, nearly 1.8 million children were involved in the experiment, and it was found to be 60 to 70 percent effective with polio type 1 and over 90 percent effective with strains 2 and 3. In 1955, a campaign of vaccination propagation occurred in the United States that aided in the lowering of polio cases to 161 by 1961. Salk received the Lasker Award for his work in immunology in 1956 and the Presidential Medal of Freedom in 1977.

Oral polio vaccines were also instrumental in lowering the instances of polio in the late 20th century. The oral vaccine is derived by passing a live strain of the virus through nonhuman cells, which in turn produces a weakened mutation.

Polish-born immunologist and virologist Hilary Koprowski claimed that he discovered the first polio vaccine while working at Lederle Laboratories in 1950. Koprowski's live, oral vaccine, however, was not out of research and testing before Salk presented his discovery to the world. Groups of clinical experimenters worked on an oral vaccine throughout the 1950s, but it was the strain discovered by Albert Sabin that would be adopted by the National Institutes of Health in 1958. The Sabin vaccine was easier to administer than Salk's and offered a longer immunity.

The World Health Organization announced in 1988 its intention to eradicate polio much as it had eradicated smallpox in the 1970s. The primary tool for

the WHO is variations of the Sabin vaccine. The last case of an endemic transmission of polio in the United States occurred in 1979 among Amish communities in the Midwestern states. Despite its great rarity in the United States and the developed world, "wild" polio-myelitis continues to occur in Africa and Asia in places without access to clean water or sanitation.

Sean P. Phillips

See also Vaccines

Further Reading

Oshinsky, David M. 2006. *Polio: An American Story*. Oxford: Oxford University Press.

Wilson, Daniel J. 2007. *Living with Polio: The Epidemic and Its Survivors*. Chicago: University of Chicago Press.

Pong

Pong is arguably the first video game to reach masses of people. Atari, an American video game company founded by Nolan Bushnell and Ted Dabney, created and released the two-dimensional ping-pong game in the summer of 1972.

The game was not initially intended for commercial release, as it was merely a training exercise for Alan Alcorn, a prospective employee who had just been hired by Atari. Alcorn was asked to create a table-tennis game that needed two paddles, a playing field for the ball to move freely on, and digits to show the score. Alcorn tweaked the game so the ball could bounce around at the angles and sides of the screen. He also made the ball bounce back and forth faster with each consecutive hit. Atari cofounder Nolan Bushnell supervised the *Pong* project and worked with Alcorn through its development. Bushnell felt that the game needed realistic sounds, such as that of a crowd, to be featured in the game. Alcorn found a way to bring them. When Alcorn fit all the major components into a wooden cabinet, Bushnell and Dabney envisioned the commercial possibilities of selling such a product.

The video game was installed at a local bar to test its favorability with consumers. Customers loved it so



Though *Pong* was first developed as an arcade game, Atari made a home use version in 1975. The *Super Pong* console, seen above, remains a gaming icon. (Sascha Steinbach/Getty Images)

much that the only problem with the game was that too many quarters were being inserted to the machine, creating technical issues. It was then that Atari decided to manufacture *Pong* at a greater scale.

The game of *Pong* made its way into living rooms around the world when Atari began developing home consoles that could plug into television sets, such as the Atari 2600. Atari signed a contract with Sears in 1975 that dubbed the Atari 2600 “Home Pong.” Sears sold nearly 150,000 units that holiday season alone.

Bushnell felt that the only way to keep up with competitors was to create sequels. Over the years after *Pong*’s initial launch, the Atari team created sequels such as *Pong Doubles*, *Super Pong*, and *QuadraPong*.

Daniel Aparicio

See also Drones; Moog, Robert; Vocoder

Further Reading

- Gomez-Palacio, Bryony, and Armin Vit. 2012. *Graphic Design, Referenced: A Visual Guide to the Language, Applications, and History of Graphic Design*. Rockport, MA: Rockport.
- Stanton, Richard. 2015. *A Brief History of Video Games*. New York: Perseus Books Group.

Portable Transistor Radio

Following the 1947 development of the transistor, Texas Instruments (TI) and Industrial Development Engineering Associates (IDEA) introduced the world’s first commercially available transistor radio, the Regency TR-1. While this first portable radio was mainly a novelty item, other portable radios based on

transistor technology flooded the market in the 1960s and 1970s.

Portable radios fundamentally changed American musical culture and American listening habits. Post–World War II economic affluence meant that many people could afford the small radios. Untethered from large, in-cabinet home radios, people could carry their music and news with them. Young people bought the small radios (or had them bought by affluent parents). Away from their homes and parental control of the family radio, young Americans could listen to music of their choosing. Popular music exploded as music production companies began to cater to the tastes of American youth.

By the late 1980s, portable tape players like the Sony Walkman largely replaced portable radios. Portable CD players and iPods followed, and each innovation made the portable radio more of a historical artifact.

Emma E. L. Burke

See also Vocoder; *Vol. 2, Sec. 2: Radio*; *Vol. 2, Sec. 3: Electric Guitar*; *Vol. 3, Sec. 3: iPod*

Further Reading

Guralnick, Peter. 1995. *The Last Train to Memphis: The Rise of Elvis Presley*. Boston: Back Bay Books.

Rocket Girls of JPL

The “Rocket Girls” of NASA’s Jet Propulsion Laboratory (JPL) were human “computers” who calculated the trajectories of rockets and created many computer programs with the FORTRAN programming language starting in the 1940s. The group was led by supervisors Macie Roberts and Helen Ling, who were inclined to hire only women due to a cultural way of thinking that men would be uncomfortable taking direction from women. There was also a stigma that the tasks that they were generally responsible for were considered “women’s work” by most, including their colleagues and the engineers above them.

This trend of an all-female group continued up to and through the 1960s before the advent of more powerful electronic computers in the 1970s that made the plotting of mission trajectories much simpler. After the introduction of these supercomputers, the need for

complex mathematical plots to be done by hand decreased, and the desire for more complex computer software increased. But these women were the first programmers at NASA.

Many of the Rocket Girls held degrees or were otherwise deeply skilled in mathematics. These female “computers” were pivotal to many of NASA’s missions, including the Explorer-1 mission that put the first U.S. satellite into Earth’s orbit and the unsuccessful Ranger missions one through six. They ultimately succeeded at landing (crashing) a spacecraft on the moon with the Ranger-7 mission and were successful at relaying data and photographs 1,000 times better than what was obtainable from the surface of the earth. During the time of the Ranger missions, the JPL set its sights beyond the moon and had sent similar spacecraft to collect data from Mercury, Mars, and Venus.

Of the many women designated as Rocket Girls at JPL, Eleanor Francis Helin is one of the most highly recognized. Helin was inducted into the Women in Science and Technology International (WITI) Hall of Fame in 1998, earning this after more than 30 years of hard work at the California Institute of Technology and at JPL. Helin’s accomplishments were many and included numerous asteroid discoveries and her role as the principal investigator for the Near Earth Asteroid Tracking (NEAT) program responsible for discovering more than 26,000 objects, including 30 near-earth asteroids, under the guidance of NASA, JPL, and the U.S. Air Force. Helin was also the recipient of NASA’s Exceptional Service Award and the 1997 JPL Award for Excellence due to her role in the NEAT program. Helin retired in 2002 and passed away in January 2009. In 1987, Edward Bowell named an asteroid after her, using her nickname Glo. Approximately 6 miles in diameter, 3267 Glo is a Mars crossing asteroid.

Other Rocket Girls of notable accomplishment include Linda Lee, who took JPL’s trajectory analysis from a mission that was to rendezvous with Halley’s comet and created one of the mission’s earliest computer animations. Lee is currently responsible for developing command and sequencing software. As of 2018, Susan Finley, who hand plotted the Ranger mission trajectories, was still with JPL working as a testing engineer and was involved in developing software for the Mars Science Laboratory Mission. Helen Ling

was yet another notable software developer and created programs used in many of the missions during her time at JPL, including the Infrared Astronomical Satellite, Magellan, Mars Observer, and Topex/Poseidon. Ling's software development skills left a lasting impression on the Voyager Mission designer, Charley Kohlhasse, who did not allow anyone else to work on his software. Helen Ling retired in 1994 to Pasadena, California, with her husband, Art.

When we try to reach another astronomical body, whether we are putting a human being on it or just a rover, it is important to do so as efficiently as possible. The Rocket Girls quickly discovered that launching a craft carrying a large ordnance of fuel when two planets are relatively close in orbit is not the best strategy. The contributions made by JPL's Rocket Girls are far-reaching and will have repercussions for many years to come. These women deserve credit for helping to land the first human on the moon and every subsequent mission since the 1940s. Their contributions will have an impact on every future mission as humans continue to explore the unknown, land a crew on Mars, and continue to search for signs of intelligent alien life in the universe.

Jeremy C. Kleve

See also Jackson, Mary Winston; Thomas, Valerie; Vaughan, Dorothy; Voyager Spacecraft; *Vol. 2, Sec. 3: Curtiss-Wright Aeronautical Engineering Cadettes*

Further Reading

Holt, Nathalia. 2016. *Rise of the Rocket Girls: The Women Who Propelled Us, from Missiles to the Moon to Mars*. New York: Little, Brown.

Jet Propulsion Laboratory. 1998. California Institute of Technology, National Aeronautics and Space Administration. Media Relations Office. "Asteroid Finder Named to Women in Technology Hall of Fame." June 24. <http://www.jpl.nasa.gov/releases/98/helinawd.html>, accessed September 26, 2018.

Jet Propulsion Laboratory. 2007. "Women Made Early Inroads at JPL." March 27. <http://www.jpl.nasa.gov/news/news.php?feature=1327>, accessed August 31, 2018.

Jet Propulsion Laboratory. 2016. "When Computers Were Human." October 31. <http://www.jpl.nasa.gov/edu/news/2016/10/31/when-computers-were-human/>, accessed August 31, 2018.

Primary Document: Press Release Announcing Eleanor F. Helin's Naming to the Women in Science and Technology International (WITI) Hall of Fame (1998)

Of the many women "computers," otherwise commonly referred to as "Rocket Girls," who worked at NASA's Jet Propulsion Laboratory in Pasadena, California, Eleanor Francis Helin is one of the most highly recognized. Helin was inducted into the Women in Science and Technology International (WITI) Hall of Fame in 1998 due to her over 30 years of effort at the California Institute of Technology and JPL, including multiple asteroid discoveries and her role as the principal investigator for the Near Earth Asteroid Tracking (NEAT) program. Helin has also received NASA's Exceptional Service Award and the 1997 JPL Award for Excellence due to her role in the NEAT program.

MEDIA RELATIONS OFFICE
JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY

NATIONAL AERONAUTICS AND SPACE
ADMINISTRATION
PASADENA, CALIF. 91109 TELEPHONE (818)
354-5011

Contact: Mary Beth Murrill
FOR IMMEDIATE RELEASE June 24, 1998

ASTEROID FINDER NAMED TO WOMEN IN TECHNOLOGY HALL OF FAME

Asteroid finder and astronomer Eleanor F. Helin of NASA's Jet Propulsion Laboratory, Pasadena, CA, has been named to the Women in Science and Technology International (WITI) Hall of Fame, an award that honors women in science and technology worldwide.

Helin will be honored at ceremonies to be held Thursday, June 25, at 7 p.m., during the WITI 1998

Technology Summit in Santa Clara, CA. The largest-ever conference of top women in technology, the WITI 1998 Technology Summit will draw more than 3,500 technologists and scientists from around the world. WITI Hall of Fame was launched in 1996 to recognize, honor, and promote the outstanding contributions women make to the scientific and technological communities and society at large. Inductees are chosen by an independent panel of judges.

Donna Shirley, manager of JPL's Mars Exploration Program, was inducted into the WITI Hall of Fame last year, and is a featured speaker at Thursday's ceremonies.

Helin has been active in planetary science and astronomy for more than three decades at the California Institute of Technology and JPL, a division of Caltech managed for NASA. She is the principal investigator for the Near Earth Asteroid Tracking (NEAT) program, a collaborative effort of NASA, JPL and the U.S. Air Force which has already detected more than 26,000 objects including 30 near-Earth asteroids.

In the early 1970s, Helin initiated the Palomar Planet-Crossing Asteroid Survey from Caltech's Palomar Observatory in Southern California, resulting in the discovery of thousands of asteroids of all types including 100 near-Earth asteroids and 20 comets. One of the most significant discoveries was that of asteroid 2026 Aten, the first asteroid found to have an orbit smaller than the Earth. Another of her asteroid discoveries, KD 1992, was recently named the new target for a flyby to be conducted in July 1999 by the NASA/JPL Deep Space 1 spacecraft, due for launch this November.

Helin is a recipient of NASA's Exceptional Service Medal and the 1997 JPL Award for Excellence for her leadership of the NEAT program. The International Astronomical Union named asteroid 3267 Helin in her honor. Helin and her husband reside in Thousand Oaks, CA.

Source: NASA. Available at: <https://www.jpl.nasa.gov/news/news.php?feature=5146>.

Rogallo, Francis Melvin (1912–2009)

Francis Rogallo was an inventor, aeronautical engineer, flight pioneer, husband, and father. His best-known contribution was the creation of the flexible wing (also known as the Rogallo wing), which was a precursor to what became the hang glider, the paraglider, and led to sport parachuting and stunt kite flying.

He was born in Sanger, California, on January 27, 1912, to Mathieu Rogallo and Marie Dajas Rogallo Betzold. In 1928, he graduated from Sanger High School and later attended Stanford University. In 1935, he received a degree in Mechanical Engineering and Aeronautics.

In 1936 in Hampton, Virginia, he joined the National Advisory Committee for Aeronautics (NACA), which later became the present-day National Aeronautics and Space Administration (NASA). In 1939, he married Gertrude Sudden Rogallo. She was a young educator from Hampton Roads. They were married for over 68 years and together, they raised four children.

Gertrude stayed busy as a housewife while her husband worked as an aeronautical engineer in the

NACA wind tunnels. At home, they worked on creating a vehicle to make flight available and affordable to everyone. While they actively pursued this passion, they met Orville Wright, who further fueled their creative spirits. Francis Rogallo had several patents through his work at NACA, but he was proudest of the flexible kite patent that was coinvented by his wife. This device that was built during their leisure time at home was one of the simplest airfoils ever made. It had no stiffeners and effortlessly created lift and carried payloads.

The couple was recognized worldwide because of their contributions to sport aviation. Together, they received honors from Australia, Japan, Switzerland, Germany, and France. Francis Rogallo also received honors individually in the United States. Francis and Gertrude Rogallo were also inducted into the Paul Garber Shrine at the Wright Brothers National Memorial, where their portrait still hangs. Francis Rogallo was inducted into the North Carolina Sports Hall of Fame and the Public Education Hall of Fame of the California School Boards Association. The couple are both honored with a pylon at the Century of Flight Monument located in Kitty Hawk, North Carolina.

In 1967, they moved to the outer banks of North Carolina, where they attended local aviation group meetings and gliding events. Rogallo joined the First Flight Society, Civil Air Patrol, and the Volunteer Fire Department of the Southern Shores.

Rogallo passed away in his home on September 1, 2009, at the age of 97. His influence on flight was so significant that the wings of hang gliders were widely known as Rogallo wings. Members of the Hang Gliding and Paragliding Association, to this day, are called “Rogallo members.”

Amanda Elaine Duran

See also National Aeronautics and Space Administration (NASA); *Vol. 2, Sec. 1: Wright, Wilbur and Orville*; *Vol. 2, Sec. 2: Airplane*; Boeing, William E.; *Vol. 3, Sec. 3: Airplane Deicer*

Further Reading

Hansen, James R. 1995. *Spaceflight Revolution: NASA Langley Research Center from Sputnik to Apollo*. NASA History Series.

Powell, Vic. 1996. “Rogallo’s Inducted into First Flight Shrine.” *Milestones* (March): 16–8.

Sabin, Albert B. (1906–1993)

Pioneering medical researcher Dr. Albert B. Sabin developed the oral live-virus polio vaccine, the vaccine of choice in most countries. Sabin’s vaccine is widely credited with eradicating polio virtually worldwide.

Sabin was born in Bialystok, Poland, in 1906 and immigrated to the United States with his family in 1921 to avoid religious persecution. After receiving his MD from New York University in 1931, Sabin began research at Bellevue Hospital, and his first polio-related article was published in 1933. Sabin joined the staff at the Rockefeller Institute in New York City in 1935, where he conducted research and first became interested in live-virus vaccines.

In 1939, Sabin took a position as associate professor of pediatrics and research fellow in virology at the University of Cincinnati College of Medicine’s Children’s Hospital Research Foundation. There, he

developed innovative approaches to understanding polio and preventing outbreaks. Although polio primarily affects the nervous system and can grow in nerve tissue, the virus also lives in the small intestine. Sabin presented the medical world with the concept of enteroviruses—viruses that live in the digestive system. He theorized that an oral vaccine might thereby be effective against this intestinal virus.

During World War II, Sabin served on the U.S. Army Epidemiological Board’s Virus Committee, working in Europe, Africa, the Middle East, and the Pacific. He identified the virus that caused sandfly fever and developed vaccines for encephalitis and dengue fever.

Sabin returned to his research on the polio virus after the war. He isolated an attenuated polio virus, a form of the polio virus that was unable to cause the disease. This weakened virus was safe to introduce into the body but could still provide protection by reproducing in the intestines and displacing the lethal forms of the polio virus. Sabin and his research associates were the first experimental subjects, followed by 30 volunteer inmates at a federal prison.

From 1957 to 1959, the oral vaccine was tested outside the United States. Because the Salk polio vaccine was already in use in the United States, researchers were concerned about possible interference in the results due to subjects who had already been vaccinated. Despite the Cold War, U.S. and Russian scientists collaborated to vaccinate 10 million Russian children. The vaccine was first available to the public in the United States in 1960 during the “Sabin Oral Sunday” campaign, and in 1961, the vaccine was approved by the U.S. Public Health Service, replacing the Salk inactive virus polio vaccine.

In 1970, Sabin became the president of the Weizmann Institute of Science, and in 1974, he began work as an expert consultant to the U.S. National Cancer Institute. He continued his research at the Medical University of South Carolina and the National Institutes of Health until his retirement in 1986. Sabin died in 1993. Sabin was awarded the National Medal of Science in 1970 and the Presidential Medal of Freedom in 1986.

Terry Steagall

See also Polio Vaccine; Salk, Jonas; Vaccines

Further Reading

Hampton, Lee. 2009. “Albert Sabin and the Coalition to Eliminate Polio from the Americas.” *American Journal of Public Health* 99, no. 1: 34–44.

Oshinsky, David M. 2006. *Polio: An American Story*. New York: Oxford University Press.

Salk, Jonas (1914–1995)

American medical researcher Jonas Salk developed the first successful vaccine against polio. Salk was born in 1914 in New York City to Russian-Jewish immigrants. He graduated with a degree in science from City College of New York in 1933, and he received his medical degree from the New York University School of Medicine in 1939, completing his internship at Mount Sinai Hospital.

In 1942, Salk accepted a position as research fellow at the University of Michigan, where he later became assistant professor of epidemiology. Beginning in 1943, his focus was on developing a killed-virus influenza vaccine, work that was largely supported by the U.S. Army. The killed-virus vaccine could not cause the disease but nevertheless was able to prompt the body’s immune system to produce antibodies that would prevent it.

As the director of the Virus Research Laboratory at the University of Pittsburgh School of Medicine, Salk began developing a vaccine for polio in 1947. This research was funded by the National Foundation for Infantile Paralysis (now known as the March of Dimes Birth Defects Foundation). The first step of the process was to sort the 125 strains of the virus. Salk identified three basic types of polio virus, which determined the number of strains that would need to be included in the vaccine. The polio vaccine would be a killed-virus vaccine like the influenza vaccine Salk had developed, because even though this approach was contrary to established scientific thought, Salk believed that it would be less dangerous.

In 1952, Salk began experimental trials of the vaccine, first administering it to himself, his wife and children, and his laboratory scientist. He followed those experiments with trials on children who had already contracted polio and found that their antibody

levels increased significantly. These results were published in the *Journal of the American Medical Association* in 1953, and a year later, a double-blind clinical trial was conducted on 1.8 million Americans, mainly children aged six to nine, who came to be known as “Polio Pioneers” in what was the largest public health experiment in American history. When the trial was found to achieve a 60 to 70 percent prevention rate, the vaccine was declared to be safe and effective in 1955.

When asked by CBS news correspondent Edward R. Morrow who owned the patent for the polio vaccine, Salk famously replied, “Well, the people, I would say. There is no patent. Could you patent the sun?” Since the expensive research and field testing had been supported by voluntary public donations to the National Foundation for Infantile Paralysis, he believed that no one person or company should benefit from the vaccine.

The viability of the polio vaccination program was threatened briefly only weeks after its launch. More than 200 children who had recently been vaccinated contracted polio; most became severely paralyzed, and 11 died. The outbreak was traced to inadequate controls at the Cutter Laboratories in Berkeley, California, which had resulted in several lots of the vaccine being contaminated with live polio viruses. Vaccination was temporarily halted by the surgeon general, but this was the only documented case of polio being contracted as the result of the Salk vaccine in the United States.

The polio vaccination effort using the Salk vaccine led to an extraordinary reduction in the number of new cases of polio. In the years between 1950 and 1955, there were between 25,000 and 60,000 cases of polio each year in the United States, while after 1955, there were only a dozen or fewer cases annually. By 1959, 90 other countries were using Salk’s vaccine. However, in 1962, the Sabin oral live-virus vaccine was introduced in the United States on a wide scale, and Salk’s injected killed-virus vaccine was eventually replaced by Sabin’s. Salk’s injected vaccine was eventually reintroduced in the United States in 2000, after Salk’s death, because the live-virus vaccine could cause polio in rare cases. The World Health Organization now recommends that polio-free countries return to using the Salk vaccine.

In 1963, Salk founded the Salk Institute for Biological Studies in La Jolla, California, with a \$20 million grant from the National Science Foundation and support from the March of Dimes. Salk's mission for the Institute was to merge the study of the humanities and the sciences, a mission that he felt was never entirely realized. Here Salk continued research on the immunological aspects of multiple sclerosis, cancer, and AIDS. In his final decade of research, Salk worked on an immunization to forestall the development of full-fledged AIDS.

Terry Steagall

See also Polio Vaccine; Sabin, Albert B.; Vaccines; *Vol. 3, Sec. 2: AIDS Research*

Further Reading

Jacobs, Charlotte DeCroes. 2015. *Jonas Salk: A Life*. New York: Oxford University Press.
Oshinsky, David M. 2006. *Polio: An American Story*. New York: Oxford University Press.

Satellites and Space Probes

A satellite is an object that orbits a planet or a sun. Man-made satellites have been purposely placed into Earth's orbit. These manufactured satellites are called "artificial" satellites to distinguish them from natural satellites such as Earth's moon, or even Earth itself. A space probe is a robotic spacecraft that does not orbit but follows a trajectory to some destination in space. American space probes have explored the moon, Mars, Mercury, Venus, Saturn, Jupiter, Uranus, Neptune, a variety of comets, and interplanetary space.

Newton's cannonball experiment was the first thought experiment for an artificial satellite. He theorized that a cannonball traveling at a certain speed would be held in Earth's orbit by gravity.

The first artificial satellite to successfully orbit Earth was the Soviet Sputnik 1. It was a metallic sphere about half a meter across, weighing 84 kilograms, and had three long prongs pointing to one side. The satellite stayed in orbit for about six months before falling back to Earth. Its rocket booster, weighing three and a half metric tons, also reached orbit and

was easily visible from the ground. Sputnik helped identify the density of the high atmospheric layers. The second Sputnik satellite was launched on November 3, 1957, and carried a dog named Laika into space. Sputnik 2 was the first satellite to carry a living passenger into orbit.

Space probes and satellites became important during the Cold War, showing how a country's science and space technology could be used to boost patriotism and create fear-based propaganda. The Soviet Union and the United States, in the so-called Space Race, competed for supremacy. The 1969 manned moon landing is often cited as the moment that the United States won the Space Race.

There are three simple classes of nonmilitary satellite services: fixed, mobile, and scientific. Data transmission around the world is handled by fixed satellite services. Mobile satellite systems help connect places with stationary communications units like vehicles and people, as well as serve in navigational systems. Scientific research satellites provide data for different scientific research applications such as earth and marine science, meteorological and atmospheric information, and amateur radio.

There are many different types of satellites. Astronomical satellites are used to observe distant celestial objects. Bio satellites carry living organisms. Communications satellites are positioned in space for the purpose of telecommunication. Recovery satellites provide recovery of many different types of payloads from orbit to Earth. Tether satellites are attached to other satellites by light, thin cables called "tethers." Weather satellites are mainly used to monitor Earth's climate and weather. There are other types of satellites as well.

Space stations are artificial orbital constructs specifically designed for human beings to live in outer space. Space stations are differentiated from spacecraft because they are in stationary orbit and do not have any propulsion or landing facilities. These stations are designed for medium-term living in orbit. The largest artificial satellite currently orbiting the earth is the International Space Station (ISS). The ISS is a habitable artificial satellite where scientists can conduct experiments in a laboratory in space. The space station was built piece by piece. The first piece was sent November 20, 1998, and the station was completed in

15 years. In 2010, the ISS was given additional diplomatic, commercial, and academic roles.

Notable space probes include Luna 3, Luna 9, and Luna 16. Luna 3 was the first mission to get a picture of the far side of the moon. Luna 9 was the first man-made object to land on the moon. Luna 16 is the first robotic probe to return a sample by reaching the moon and coming back. Many other space probes are important to astronomy.

Launched on September 5, 1977, the *Voyager 1* probe weighed 700 hundred kilograms. As of January 2019, *Voyager 1* was still operational, part of the longest-lasting NASA mission, having been in service more than 40 years. *Voyager 1* was the first probe to send detailed images of the moons of Jupiter and Saturn. Now the farthest human-made object from Earth, *Voyager 1* has sped away from the solar system at a higher speed than any other probe. As of January 2019, *Voyager 1* was over 21.5 billion kilometers from the sun. On August 25, 2012, *Voyager 1* became the first human-made object to leave the solar system and the influence of the sun and enter interstellar space. The plasma sensor on *Voyager 1* ceased to function in 1980, but NASA scientists were able to use a 2012 solar flare to measure vibrations of the plasma surrounding the craft, allowing them to determine that the plasma was much denser than it had been in the far layers of our heliosphere. From this, they concluded that the craft had broken beyond the heliopause.

The Cassini-Huygens space probe to Saturn launched in 1997 and entered Saturn's orbit in 2004. Later that year, the Huygens probe separated from Cassini and landed on Titan, one of Saturn's 53 moons. The Cassini probe has made innumerable discoveries, including the existence of large methane lakes on Titan and an ice-covered sea on Enceladus. In September 2017, the probe crashed into the surface of Saturn as its "grand finale."

Satellites and space probes are still being made today to advance our space travel and exploration. The number of satellites is limited because of waste in orbit; however, more deep space exploration probes are still planned actively today.

Lenny Yang

See also Apollo Project; Comsat/Intelsat; Jet Propulsion Laboratory (JPL); National Aeronautics and

Space Administration (NASA); *Voyager Spacecraft*; Vol. 3, Sec. 2: Satellite Radio; Space Shuttle; Vol. 3, Sec. 3: Hubble Space Telescope

Further Reading

Godwin, Robert, ed. 2005. *Deep Space: The NASA Mission Reports*. Apogee Books.

Rhodes, Richard. 2000. *Visions of Technology*. New York: Simon & Schuster.

Scotchgard Fabric Protector. See Sherman, Patsy O'Connell

Sherman, Patsy O'Connell (1930–2008)

Patsy Sherman was a chemist who, along with colleague Sam Smith, invented Scotchgard Fabric Protector, a moisture and stain repellent, while employed at 3M Company in the 1950s. The discovery of the substance was largely by accident—when someone in the lab spilled a new latex material onto a shoe and Sherman discovered that it could not be washed off. She and her supervisor began to think of possible applications for such a waterproof material, and in 1955, Sherman and Smith introduced Scotchgard, a protective coating for fabrics and other materials.

Sherman began working for 3M immediately after college and remained there for 40 years, until her retirement in 1992. She rose through the ranks from research specialist to manager of the chemical resources division to head of technical development and held several patents for fluorochemical polymers and processes.

The Scotchgard product made 3M a household name and earned the company millions of dollars, but in 2002, it was announced that 3M would remove Scotchgard from the market over environmental concerns. The property that had made its chemical makeup attractive as a fabric protector, its insolubility or inability to be broken down, also made it potentially dangerous. Although tests of potential toxicity to humans and to the water supply remain inconclusive, elevated levels of perfluorochemicals have been found in the blood of company employees as well as in certain animal species. In light of this research, 3M chose to exercise

what it called “responsible environmental management” in phasing out the current chemical process used to create Scotchgard products. The product is still available as the company experiments with alternative formulas, and government organizations will continue to monitor the potential environmental and health effects of perfluorochemicals.

Sherman was committed to science education and was often an invited speaker to serve as a role model for young students. She received the Joseph M. Biedenbach Distinguished Service Award of the American Society for Engineering Education in 1991. In 2001, she was inducted into the National Inventors Hall of Fame, one of only a handful of women to be so acknowledged, and in 2002, she was one of 37 inventors who appeared at a celebration of the 200th anniversary of the U.S. Patent and Trademark Office. She was a longtime member of the American Chemical Society.

Tiffany K. Wayne

See also *Vol. 2, Sec. 1*: Richards, Ellen Swallow; *Vol. 2, Sec. 2*: McKnight, William L.; Noether, Amalie Emmy

Further Reading

Wayne, Tiffany K. 2010. *American Women of Science since 1900*. 2 vols. Santa Barbara, CA: ABC-CLIO.

Shippingport Atomic Power Station

The Shippingport Atomic Power Station in western Pennsylvania was the first full-scale nuclear electric power plant meant exclusively for peacetime uses. Its location was the Beaver Valley, about 25 miles from downtown Pittsburgh. Pittsburgh’s Westinghouse Electric built the reactor. It was managed by Duquesne Light Company and went on the grid in August 1956. The power station was built in 32 months at a cost of \$72.5 million. It was an experimental reactor known as a “light water thermal breeder” and was distinguished by its ability to transmute inexpensive thorium-232 to a fissile fuel, uranium-233. Shippingport had a modest capacity of 60,000 kilowatts. Its basic function was

creating heat from nuclear fuel fission to generate steam to turn turbines, thus generating electricity. It was the first result of President Dwight Eisenhower’s Atoms for Peace program. After 25 years of successful service, Shippingport became the first nuclear reactor to be successfully decommissioned (this was completed in 1985). Atoms for Peace was one of the successful government and business programs that founders Alexander Hamilton and Henry Clay had envisioned, and it ranks with the Erie Canal, National Road, the Hoover Dam, and the 1960s U.S. space program.

The high cost involved in research and development and construction required an alliance of business and government. Duquesne Light teamed up with the new Atomic Energy Commission of the Eisenhower administration and committed \$30 million to the project over five years. Duquesne Light’s commitment came from its use of coal in the already smog-filled skies of the steel city of Pittsburgh, which often had the sun blotted out by smog in the afternoon. Smog and soot had plagued the area for over a century. Shippingport was a blend of efforts by the navy’s Admiral Hyman Rickover, Duquesne Light Company, Westinghouse Electric, and the Bettis Atomic Power Laboratory under the political leadership of President Eisenhower. Such a government-corporate alliance would take strong leadership, and that leadership is attributed to Admiral Rickover. The Atomic Energy Commission supplied 90 percent of the overall costs and assumed the legal liability for the project. Westinghouse Electric functioned as the general contractor for the construction. The project required government support, because fossil fuels were abundant at the time.

Admiral Rickover would leave a distinctive mark on America’s nuclear energy industry. He had been working with Westinghouse Electric since the early 1950s to develop nuclear submarines and aircraft carriers for the navy. Rickover had been behind the building of the Bettis Atomic Power Laboratory outside Pittsburgh in 1948. It was here that the Mark I submarine nuclear reactor was built at a cost of \$30 million. Rickover’s success made him the logical candidate to head up the Atomic Energy Commission in 1953. Rickover approached Shippingport as an example of

peaceful uses for atomic energy. He demanded reliability and safety throughout the design-and-construction phase. In addition, he required low-grade fuel versus enriched uranium in order to prevent diversion of nuclear fuel elements from use in nuclear weapons. The Shippingport plant was built specifically to advance the use of nuclear power, and it was to be a model for the future. Rickover's attention to the safety mission and his autocratic management style won over the public, allaying its concerns about nuclear energy. Rickover continued the development of nuclear submarines using the same technology. As construction started at Shippingport in 1954, the USS *Nautilus*, the nation's first nuclear submarine, was launched. The design of the nation's first nuclear aircraft carrier, the USS *Enterprise*, was started in 1954 as well, and it launched in 1960. The navy's outstanding safety record in nuclear propulsion remains part of the Rickover legacy.

Positive publicity was a key goal of both Atoms for Peace and the construction of the Shippingport plant. On September 6, 1954, President Eisenhower waved a neutron wand in Denver, Colorado, to signal a bulldozer in Shippingport to start construction. Eisenhower's address was televised to workers and guests at the construction site. Shippingport functioned faultlessly up to 1964, when it was shut down to install a new core to expand the capacity to 100,000 kilowatts. In 1974, the plant was shut down for a mechanical problem in the turbine. The Department of Energy used the time to convert Shippingport to a light water breeder reactor. President Jimmy Carter dedicated the new reactor in 1977. Carter was a nuclear engineer and a graduate of the navy's nuclear submarine program. The plant was decommissioned in 1982 after 25 years of very successful operation. General Electric was hired to be the general contractor to do the shutdown, deconstruction, and cleanup. Final deconstruction was completed in 1985 at a total cost of \$98 million. The site was graded, seeded for grass, and turned over for unrestricted use.

Shippingport proved the economic feasibility of breeder technology. The breeder reactor concept was based on the scientific principle that a reactor using low-grade fuel could produce more nuclear fuel than it consumed. However, the cheap availability of enriched

uranium allowed more conventional reactors to dominate the future market for nuclear power plants. The safety record of the plant was near perfect, thanks to redundant containment design, which assured no escape of radiation to the environment. The design used low-pressure steam created in a secondary exchange of heat, which isolated this secondary water from the radioactive inner system. In general, nuclear power gained wide acceptance thanks to Shippingport, until the Three Mile Island accident in 1979 (ironically a mere 80 miles east of the Pittsburgh area).

Quentin R. Skrabec

See also Nuclear and Radiation Accidents; *Vol. 2, Sec. 3: Manhattan Project*; *Vol. 3, Sec. 2: Nuclear Energy/Nuclear Power Plants*; Solar Energy; Wind Energy

Further Reading

Beaver, William. 1990. *Nuclear Power Goes On-Line: A History of Shippingport*. Westport, CT: Greenwood Press.

Cravens, Gwyneth. 2007. *Power to Save the World: The Truth about Nuclear Energy*. New York: Knopf.

Silent Spring (1962)

Rachel Carson's (1907–1964) book, *Silent Spring*, calls attention to the dangers of the widespread overuse of synthetic chemical pesticides. The book was translated into several languages and was a worldwide best seller. Two important documentaries on the book were broadcast on television (CBS, 1963 and PBS, 1993). The book has been credited with the rise of the environmentalist movement of the 1970s. Unfortunately, Carson, already a national literary celebrity before she wrote the book, did not witness the full extent of her influence, because she died from breast cancer two years after its publication.

In the book, Carson argues that human tampering with nature can have disastrous results. Carson explains the multifaceted problem in a clear and moving text, suggests some natural alternative pesticides, and challenges the government and society to make necessary changes. She also argues that scientists'

desire to control nature is founded on an arrogant belief in the superiority of science and technology. She argues that all living things on the earth, from the tiniest microbes to the largest mammals, are part of the same fabric of nature. If one part of the fabric is abused, the negative effects are felt by the rest of the plants, animals, and humans. For example, when synthetic toxins are applied to insects, all the life-forms that are higher on the food chain ultimately ingest the same poison.

Carson formed the idea for an article on the possible harmful side effects of the use of synthetic chemical pesticides after a friend informed her that birds were dying in her hometown after local authorities sprayed dichlorodiphenyltrichloroethane (DDT) to control mosquitoes.

Before World War II (1939–1945), exterminators often used arsenic-type pesticides to get rid of unwanted insects. Although these types of poisons had harmful side effects, they paled in comparison with the strength of the pesticides that were developed and deployed after the war. This phenomenon occurred due to two main reasons. First, the high degree of specialization in research and development led to the fragmentation of scientific knowledge. For example, a scientist developing an effective pesticide to control a certain insect population was unlikely to consider the pesticide's harmful effects on birds or fish. Second, perhaps due to the legacy of the war, pesticide manufacturers tended to think in terms of waging “total war” on an enemy. Therefore, they developed synthetic toxins (much more powerful than natural toxins) with the ability to saturate and devastate target areas over an extended period of time. The feature of extended saturation, according to Carson, is instrumental in causing all sorts of health problems, including cancer.

Carson relied on her undergraduate and some graduate background in zoology and her gift for clear but poetic expression to create a compelling case. In spite of Carson's standing as a writer, she had difficulty finding a willing publisher. After some time, Houghton Mifflin (a book publisher) was her only outlet. Consequently, she expanded her article into a book with more than 200 pages. Critics questioned Carson's credentials and labeled her an emotional alarmist. They argued that synthetic pesticides were safe and

that no scientific proof existed of a definite link between pesticides and cancer.

Carson did not call for an end to the use of all pesticides. She acknowledged that pest control was necessary for agricultural production. She also accepted the realities of free enterprise, in which businesses often value quick profits over concern for possible long-term environmental issues. Carson called for a more controlled use of pesticides, and she made specific recommendations for the use of certain more environmentally safe natural pesticides. She held politicians, more than any other group, responsible for the state of affairs, because she believed that they were put in office to serve the public good. Government agencies responded to Carson's challenge with the creation of regulation agencies. Although very few pesticide-related laws were passed, the book created a lasting awareness in government and in society of the need to balance technological innovation with public safety.

Rolando Avila

See also Carson, Rachel

Further Reading

Carson, Rachel. 2002. *Silent Spring*. 40th Anniversary Edition. Boston: Houghton Mifflin.

Lytle, Mark Hamilton. 2007. *The Gentle Subversive: Rachel Carson, Silent Spring, and the Rise of the Environmental Movement*. New York: Oxford University Press.

Silicon Valley

Northern California's Silicon Valley is the world's major hub for technology companies. Silicon Valley holds the headquarters for some of the world's largest companies, such as Netflix, Google, Tesla Motors, and Silicon Graphics, just to name a few. The estimated net worth of Silicon Valley is estimated to be around \$2.8 trillion. Silicon Valley has paved the road for innovation with new ideas and concepts, using technology to elevate services, products, and business to new heights.

The fabled Silicon Valley rests in the southern region of the San Francisco Bay Area. It lies in the



Northern California's Silicon Valley serves as the global center of electronic technology. Corporate giants like Adobe, Apple, and Google have headquarters there. (Ken Wolter/Dreamstime.com)

Santa Clara Valley within the county of Santa Clara, California. At the end of the 1800s, it was a key location for telegraph and radio companies, and so it was already part of the history of technology before it earned its name. It was the first location the United States to do a ship-to-shore wireless message by telegraph because of its optimal ports. This act of long-distance communication helped springboard wireless communication to the world. In 1909, it became the area with the first-known radio station in the country, which was in San Jose, California: KQW.

In 1933, the U.S. Navy purchased Moffett Field, which led to the government's huge investment in the area for technology and testing for military purposes. Moffett Field has been a major location for the study of aerospace engineering and flight. Ames Research Center was established in 1939, and new jobs encouraged people to move into the vicinity. The most notable employer was Hewlett-Packard (HP), founded by William Hewlett and Dave Packard. HP made radar

and artillery technology during World War II, and it has been an important technology company since.

William Shockley, John Bardeen, and Walter Brattain created the transistor at Bell Labs in 1947. In 1954, Shockley left Bell Labs and created his own transistor company in Silicon Valley, using silicon as a key component in his work. This would help give Silicon Valley its name. Shockley Semiconductor Labs revolutionized the creation of transistors by using silicon instead of germanium. It hired people from Stanford University, experimenting and revolutionizing the electronics industry. When eight of Shockley's employees quit to create their own company, they were dubbed the "Traitorous Eight"; they were Victor Grinich, Julius Blank, Eugene Kleiner, Jean Hoerni, Jay Last, Gordon Moore, Sheldon Roberts, and Robert Noyce.

The Traitorous Eight partnered with Sherman Fairchild and created a new company called Fairchild Semiconductors. They built hardware for the Apollo

space program, which further cemented the importance of these technologies. Eventually, some of the Traitorous Eight left and created their own companies. Xerox opened and created the PARC Lab in 1970, which created technologies such as Ethernet computing and an early graphical user interface. Dan Hoefler wrote an article called “Silicon Valley U.S.A.,” and the nickname stuck.

With the creation of the personal computer and the Internet, other companies flooded the computing field, including Atari, a company that created video games. Apple also moved to Silicon Valley, and by 1980, it was already showing signs of being a hub of computing technology. Companies like Google and PayPal were making waves around the world from humble beginnings. Growth has not slowed, with Tesla Motors and Uber appearing, just to name a few.

Silicon Valley always will be linked with the improvement of humanity with technology. Starting with its humble beginnings in radio, its wide range of companies today tackle all aspects of life and business as technology continues to improve. Silicon Valley is the home and very face of technology. It is where technological ideas thrive and change never stops.

Christian Amaya

See also ARPANET; Atari; Military-Industrial Complex; Xerox Corporation; *Vol. 2, Sec. 2*: Bell Telephone Laboratories; *Vol. 3, Sec. 2*: Apple; Internet; Microsoft; SEMATECH; *Vol. 3, Sec. 3*: Video Game

Further Reading

Berlin, Leslie. 2017. *Troublemakers: Silicon Valley's Coming of Age*. New York: Simon & Schuster.
Shueh, Sam. 2009. *Silicon Valley (Images of America)*. Mount Pleasant, SC: Arcadia.

Single-Chip Microprocessor

A single-chip microprocessor is a central part in most computerized devices today, such as personal computers and smartphones. It is a processor for a computer that allows the functions of a computer's central processing unit, also known as a CPU, to take place on a single integrated circuit or a few integrated circuits. A

microprocessor is not limited to a single use; rather, it is multipurpose, processing data that is instructed to be stored in memory and then displayed. Microprocessors contain both combination logic and sequential digital logic. Microprocessors operate based on numbers and symbols represented with the binary system.

The term “microprocessor” was first used to describe a custom integrated circuit that Viatron Computer Systems used in what was known as “System 21,” a small computer system announced in 1968. By the late 1960s, many computer designers, including IBM, the biggest competitor in technology at the time, aimed to integrate computer processing unit (CPU) functions onto MOS LSI chips (MPUs).

Intel, in 1968, introduced the first commercial four-bit microprocessor, known as the Intel 4004. Bits, a measure of the power of a microprocessor, allow processors to function. The more bits, the more effective the processor. The four-bit chip gave some weight to the prediction known as Moore's Law: that the capacity of integrated circuits doubles every two years.

Intel released the first 8-bit microprocessor, the 8008, in 1972. Many other companies had become interested in developing microprocessors, but by the mid-1970s, Intel introduced the 8080, an eight-bit microprocessor that had a huge impact. By the mid-to-late 1970s, 16-bit and 32-bit microprocessors appeared. But 16-bit microprocessors were short-lived, as they were slow though more technically advanced. National Semiconductor entered the field with the PACE microprocessor, but it was also slow. By the 1980s, 32-bit microprocessors began to hit the market, introduced by National Semiconductor and Hewlett-Packard. These are seen as the forerunners of modern microprocessors.

By 1992, 64-bit microprocessors were available and became mainstream in personal computers. Intel and AMD had by then dominated the battle of microprocessor advancements. Finally, RISC microprocessors from the mid-1980s to early 1990s were initially used for special machines, but they gained wide acceptance. RISC chips were intended to be the dominant chip by limiting more complex instructions and relying more on simpler ones, allowing for quick responses. RISC chips are still used today, although they are not as common as 64-bit chips.

One of the earliest uses for microprocessors was in electrical calculators. Today, they are used in many devices such as cell phones, personal computers, and cars. The single-chip microprocessor has advanced over the past century, yet the development of this technology is not over; nor has it likely even peaked. Microprocessors will open the door for many more creations, and should permit even more transistors to be placed within them. Moore's Law of doubling capacity every two years stood the test of time for a while, but now it is unclear whether it can withstand the challenges of further advancements.

Enrique Garcia Villa

See also Vol. 3, Sec. 2: Microsoft; Vol. 3, Sec. 3: Wireless Communication

Further Reading

- Axelsson, Jay. 1994. *The Microcontroller Idea Book: Circuits, Programs & Applications Featuring the 8052-BASIC Single-Chip Computer*. Madison, WI: Lakeview Research.
- Maurukas, Tadas. 2013. *Gold Content List in Ceramic CPU's Processor Chips*. Amazon Digital Services.
- Muller, Paul, and Yusuf Leblebici. 2007. *CMOS Multichannel Single-Chip Receivers for Multi-Gigabit Optical Data Communications*. New York: Springer.

Skylab

Skylab was a U.S. space station that three crews occupied between May 1973 and February 1974 and conducted countless experiments and observations on. After several years, the space station fell back to earth. Perhaps Skylab's greatest achievement was fostering support for the space program as the public became fascinated with space technology and innovation.

Six years before the manned Apollo spacecraft landed on the moon in 1969, the National Aeronautics and Space Administration (NASA) began the Apollo Applications Program (AAP). Skylab was the size of a small house and weighed about 100 tons (on earth). It had four separate units. The Orbital Workshop (OWS),

the main unit, was a cylinder 14 feet long and 22 feet wide, with a volume of 9,550 square feet. OWS housed food lockers, refrigerators, water tanks, space suit lockers, crew quarters, and an experiment station. Another smaller unit (AW) contained the station's control and monitoring center and access for crew members to conduct space walks. Skylab also contained the Apollo telescope mount (ATM), a powerful telescope not hampered by Earth's clouds or atmosphere. The space station contained a multiple docking adapter (MDA), which was used to dock with Apollo spacecraft that transported crew members from and to Earth.

Besides the four units, the space station contained tons of scientific equipment. For example, it contained various types of cameras such as spectrometers (instruments that measured wavelengths of light) and ultraviolet telescopes (instruments that measured the portion of the electromagnetic spectrum with shorter wavelengths than visible light). The total length of the space station and an attached Apollo spacecraft was 120 feet. AAP's plan was to reuse hardware from the Apollo program to build Skylab. After the Apollo 20 mission was canceled, for example, engineers repurposed a Saturn V rocket into the station's OWS unit.

The unmanned Skylab 1 mission was successful in getting the space station into orbit on May 14, 1973. However, Skylab was damaged during liftoff when a protective shield came loose and smashed against the station's two main solar panels. One panel was completely destroyed, and the other was badly damaged. Consequently, Skylab 2, the mission to get a crew on board the station, was postponed for several days as engineers and the crew devised ways to fix the damage. Without the protective shield, parts of the station were uninhabitable due to high temperatures up to 135°F.

In addition, the station's energy levels were drained to one-third capacity due to the inoperability of the two main solar panels. As soon as the Skylab 2 crew arrived on Skylab, it conducted space walks to repair the damage on the exterior of the space station. It deployed a gold parasol-type sunshade to replace the missing shield, which cooled the station enough to allow the crew to work inside. After days of trying, on day 14, the crew fixed one of the main solar panels. Full power was restored, and the crew spent many

hours conducting planned space-environment-type experiments.

The Skylab 2 crew spent 28 days in space. When it returned to Earth, doctors found that weightlessness had caused dramatic negative effects on its members' health. The crew lost about 10 percent of their body weight, 10 percent of their red blood cells, 30 percent of their arm strength, and 60 percent of their leg strength. However, the health of the two next crews fared much better as a result of the implementation of a more intense exercise routine. In fact, later crews installed a makeshift treadmill. After securing themselves, crew members would slide-walk on a Teflon sheet while wearing socks. The Skylab 3 crew lasted 59 days in orbit, and the Skylab 4 crew lasted 84 days. All crews experienced motion sickness, but they all adjusted to the weightlessness after a few days.

All three crews conducted experiments and made observations in space. They explored the effects of weightlessness on the central nervous system, cells, embryos, fluids, magnetics, crystal growth, and particle physics. Some of their experiments had been requested by American students. For example, a high school student wondered if spiders would be able to spin their webs in space. Two spiders were transported to Skylab. At first, the spiders had a difficult time making their webs, but they adjusted after a few days. The crews also observed celestial objects in space including the earth (99 passes), the sun (941 man-hours), and the comet Kohoutek (which had been discovered in March 1973).

Although the project experienced difficulties, many scientists assessed that the Skylab missions had been a success. In total, all three crews conducted almost 300 experiments and spent 171 days in space, which was longer than all previous American manned space missions combined. Skylab fostered the public fascination with space technology and increased support of the space program in general. Another important result was that Skylab showed that weightlessness was not an absolute prohibitive barrier for human space exploration. After the Skylab 4 crew returned to Earth in early 1974, the space station was left unmanned for several years.

Engineers had not equipped the station with an independent reboost mechanism. Consequently, when the space station began to slowly lose orbit, a rescue

mission was planned. However, the station fell to earth (July 11, 1979) before a crew could save it. Skylab burned up and broke into many pieces as it reentered Earth's atmosphere. Debris was scattered over the Pacific Ocean, Indian Ocean, and a sparsely populated region of western Australia. No major damage was caused. The end of Skylab simultaneously signaled the end of the Apollo era and the beginning of the Space Shuttle and International Space Station eras.

Rolando Avila

See also Satellites and Space Probes; Space Science and Technology; Voyager Spacecraft; *Vol. 3, Sec. 2: Space Shuttle*; *Vol. 3, Sec. 3: International Space Station*

Further Reading

- Compton, W. David, and Charles D. Benson. 2011. *Living and Working in Space: A NASA History of Skylab*. Mineola, NY: Dover.
- Shayler, David. 2001. *Skylab: America's Space Station*. New York: Springer.

Skywalker Ranch

George Lucas's Skywalker Ranch is a private movie-making retreat and the home of Skywalker Sound and the George Lucas Educational Foundation. George Lucas bought land in 1978, intending his ranch there to be a place of film-making collaboration.

Skywalker Ranch is located in Marin County, California. George Lucas bought Skywalker Ranch for \$100 million; it consists of 4,700 acres with 14 buildings, animals, vineyards, a restaurant, a hilltop observatory, a theater, a hotel, soundstages, postproduction studios, and the Lucasfilm Research Library. Sprocket Systems, the company that produced the sounds in *Star Wars*, moved to Skywalker Ranch in 1987 and change its name to Skywalker Sound. Skywalker Sound has over 500 employees and fills 150,000 square feet of space. The theater called the Stag has an advanced sound system, multiple screening rooms, and underground parking.

Many top film directors have worked at Skywalker Ranch. Clint Eastwood used Skywalker Sound to produce his audio for *Million Dollar Baby*. Sean Penn

and Paul Thomas Anderson worked on their films *There Will Be Blood* and *Into the Wild* there. Tom Hanks also used Skywalker Ranch as a resource for his famous film *Cast Away*, which was nominated for two Oscars. Skywalker Sound has worked on other famous films such as *Star Wars: The Force Awakens* and *Jurassic World*. Skywalker Sound works on about 40 movies a year. Skywalker Sound is the main reason that people visit Skywalker Ranch.

Many residents around Skywalker Ranch claim that it creates light and noise pollution. Lucas submitted plans to build a studio on the property over 25 years ago, but area residents have blocked his efforts to complete the project. Lucas was also blocked in his efforts to build affordable housing for the teachers and police personnel who could not afford to live in Marin County. Marin County planners and elite-class residents have enthusiastically blocked these plans.

George Lucas wanted to create his own library to help Lucasfilm productions. In 1978, the Lucasfilm Research Library was established in Los Angeles offices. In 1985, Lucasfilm Research Library was moved to the main house at Skywalker Ranch. It has been said that to enter the library is to enter the brain of George Lucas. George Lucas's art collection also resides at Skywalker Ranch.

In 2007, Lucas was given permission to build two more screening rooms in his theater. In 2015, he intended to provide 225 units of affordable housing at the ranch. Ultimately, he would like the ranch to become a film school.

Wences Jose

See also Silicon Valley

Further Reading

Champlin, Charles. 1997. *George Lucas: The Creative Impulse—Lucasfilm's First Twenty-Five Years*. New York: Harry N. Abrams.

Smallpox, Eradication of

Smallpox was a deadly viral disease that decimated populations and wiped out armies. Caused by the variola virus, it was probably originally carried by rodents

and made a jump to humans. Where this first occurred is unknown, but it likely began in an area such as Egypt's Nile and/or India's Ganges River valleys, which were densely populated enough for the virus to pass from person to person. Symptoms include a high fever and a rash that turns into sores that break open and release more virus. The sores scab over and heal, often leaving severe scars. About 30 percent of smallpox victims die.

As early as the 10th century, it was noted that people who survived smallpox never caught it again. From there, the practice of variolation began. Named after the virus itself, variolation involved making a scratch in the skin of a healthy person and introducing material from a sore from a patient with active smallpox, which caused a less severe form of the illness. This procedure did carry some risk; variolated people could still spread the disease, and some died.

In the United States in 1716, famed Puritan minister Cotton Mather (1663–1728) wrote to the Royal Society of London about a method of inoculation that seemed to cure smallpox. He had learned it from an enslaved member of his household, Onesimus, who had described undergoing a similar inoculation in his childhood in Africa and claimed that being injected with a small form of the virus had prevented him from developing smallpox despite exposure to many other victims. In 1721, Mather used the process himself to help fight one of Boston's many epidemics. In 1736, Benjamin Franklin, devastated by the loss of his son to the disease, suggested and likely funded the creation of a pamphlet explaining inoculation to parents. Some 2,000 pamphlets were distributed.

In 1738, some 800 people in Charleston, South Carolina, were inoculated, and when smallpox hit, only eight deaths were reported. When this story reached London in 1743, it led to the practice being revitalized there.

In 1945, the United States joined 26 other allies from World War II in creating the United Nations to foster cooperation among countries. One of its outgrowths was the World Health Organization, which was established in 1948. At WHO's annual World Health Assembly in 1958, Viktor Zhdanov, the Union of Soviet Socialist Republic's (USSR) deputy minister for health, made a proposal for a program to eradicate

smallpox. At that time, smallpox had already been eliminated in the USSR, North America, and Europe, and he saw global elimination of the illness as a very real possibility. He argued that funding an eradication program would save money in the long term, as countries that were already free of the illness were forced to spend large sums on vaccination and revaccination of its citizens. His proposal was accepted in 1959.

The initial program was small, with two staff people and less than \$100,000 in cash and donations. The dearth of funding made progress slow until 1966, when WHO adopted the Intensified Smallpox Eradication Programme, partly as a result of a funding pledge from the United States. The new program came with greater resources, including an initial budget allocation of \$2.4 million, and a goal of eliminating smallpox by 1976.

The public was made aware of efforts via print publications, television documentaries, news stories, and even commemorative stamps issued by a number of countries. WHO worked with laboratories to assure adequate stocks of vaccine. Between 1967 and 1979, 360 million doses were distributed to 70 countries and organizations.

Another vital piece was surveillance and data collection—ensuring that suspected cases of smallpox were promptly reported and investigated, and using the number of new cases as a measure of program efficacy. From there, it could be determined for each country what steps should be taken to keep the number of cases going down. Any smallpox patients found were quarantined (usually at home) to prevent further spread.

The last naturally occurring case was in a hospital cook in Somalia in October 1977. WHO officially declared smallpox eradicated on May 8, 1980.

Nancy Beach

See also Polio Vaccine; Vaccines; *Vol. 1, Sec. 1*: Franklin, Benjamin; Onesimus

Further Reading

Glynn, Ian, and Jennifer Glynn. 2004. *The Life and Death of Smallpox*. New York: Cambridge University Press.

McCandless, Peter. 2011. *Slavery, Disease, and Suffering in the Southern Lowcountry*. New York: Cambridge University Press.

Smoke Detector

A smoke detector is a device that is designed to alert homeowners and businesses to the presence of fire by detecting smoke. In 1965, Dewey Pearsall invented the first affordable, battery-powered smoke detector for home use.

Prior to Pearsall's invention, smoke detectors were bulky, expensive, and unreliable. In 1890, Francis Upton patented the first automatic fire alarm, and in 1902, Englishman George Darby invented the first smoke detector.

Pearsall graduated from the University of Denver in 1947, and after serving in the Naval Air Reserve for six years, he went to work at Honeywell, a heating and air-conditioning company. In 1955, he left Honeywell to found Pearsall Company and then eight years later, Statitrol Corporation. It was at Statitrol that Pearsall realized that a mechanism designed to measure ion airflow could also be used to detect smoke. Pearsall designed a small home smoke detector that could be powered by a battery. He patented his design in 1973, and his company began to produce the "SmokeGard 700" two years later. Pearsall also worked with the National Fire Protection Association to change building codes to require smoke detectors. Pearsall sold his device to Emerson Electric in 1980.

Today, smoke detectors are found in the vast majority of American homes. The National Fire Protection Association believes that smoke detectors reduce fire-related injuries and deaths, but only if the smoke detectors are installed correctly and tested regularly.

Peg A. Lamphier

See also *Vol. 1, Sec. 1*: Fire Safety; *Vol. 2, Sec. 1*: Bee Smoker

Further Reading

Ferguson, Lon H., and Christopher A. Janicak. 2015. *Fundamentals of Fire Protection for the Safety Professional*. Lanham, MD: Bernan Press.

Primary Document: Chris P. Borreson's Account of the Iroquois Theater Fire (1904)

This recounting of the famous Iroquois Theater Fire by Chris P. Borreson, one of the few survivors, expresses the difficulty that people had in escaping the theater due to poor fire preparation and lack of fire safety regulations when the theater was constructed. This fire is one of the most important in the history of U.S. fire safety because the incident led to the development of comprehensive fire laws, maximum occupancy requirements, and many other aspects of modern fire safety. Borreson's recollection emphasizes the damage that this fire caused and the problems that people had escaping a large building without any clear exits.

Chicago, Jan 12, 1904—Dear Brother and Parents: I am all right. I was in the theatre at the time of the fire with some of my friends, but I managed to get out alive. I was badly hurt on the arm and leg. I just got out of the hospital today and could not answer your letters any sooner. The fire was the worst thing I ever

saw or was ever in. All the boys had their girls along. I had a time to get the young lady and her sister, who were with me, out. But we did get out, but we had a job of it. Everybody went away and the smoke and fire were terrible. I was behind the girls and when we got to the door, pushed them out and then we all went down the stairs. That is the way I got my arm and leg hurt. I don't know how I got out after that. The next morning I found myself in the hospital. I will not be able to do any work for a month or so. I do not care to get in a place like that again. I will be all right in a few weeks. Tell mother that I am O.K. I lost my hat and one shoe in the fire and my coat was torn all to pieces and I got a bad knock on the head that put me to sleep. I hope you are all well. Best regards to all, your brother, Chris Borreson Chicago, Ill.

Source: *Omaha Daily Bee*, January 16, 1904.

Space Science and Technology

The interest in what may lay outside of the earth's grasp has always been an enticing subject. Isaac Newton and Galileo Galilei theorized about what might be outside of the earth's atmosphere. In the early 1680s, Newton developed the idea of gravity as well as his laws of physics. Galileo Galilei is considered the inventor of the optical telescope. In the United States, the National Aeronautics and Space Administration (NASA), founded in 1958 by President Dwight D. Eisenhower, focuses on space science and technology.

Since the inception of NASA, the United States has made great progress in expanding the boundaries of what we know about space. Keith Glennan was an early NASA administrator; a letter to him from President Eisenhower mentions meteorological satellites that it sent up in its first three years—such as Trios I

and Trios II, which promised to revolutionize meteorology and global communication.

NASA has moved from such satellites to sending unmanned spacecraft to such celestial bodies as Comet 67P/C-G, the asteroid 25143 Itokawa, the moon, Venus, Mars, and Titan (Saturn's largest moon). NASA also landed a manned spacecraft on the moon in July 1969 and sent unmanned spacecraft to circle around the dwarf planet Pluto.

The Mars rover *Curiosity* functions 225 million kilometers away from earth and is self-sufficient without maintenance. It can trek up to 100 meters (328 feet) every Martian day. The Mars Rover transmits data at about 12,000 bits per second, but it can do this directly to Earth only between 90 minutes to five hours per day due to power limits and thermal conditions. The Rover is currently searching for early signs of life because of the evidence of water on Mars.

Space science and technology is a rapidly expanding field. From the speculations of Isaac Newton and the observations of Galileo Galilei, NASA is taking further steps in discovery, laying a foundation for future scientists to build upon.

Anthony Bekdas

See also National Aeronautics and Space Administration (NASA); *Vol. 3, Sec. 3: Mars Rover Series*

Further Reading

Galilei, Galileo, and Raymond John Seeger. 1966. *Men of Physics: Galileo Galilei: His Life and His Works*. New York: Pergamon Press.

NASA: *50 Years of Exploration and Discovery*. 2008. Tampa, FL: Faircount Media Group.

Steele, Philip. 2007. *Isaac Newton: The Scientist Who Changed Everything*. Washington, D.C.: National Geographic Society.

Primary Document: Account of Astronaut David Alexander Wolf Voting in Space (1997)

Astronaut David Alexander Wolf is on the record for taking four flights into space, seven spacewalks, and spending 128 days on the Mir Space Station. Before becoming an astronaut, Wolf earned degrees in both medicine and electrical engineering. He is also remembered for being the first American astronaut to vote while in space, which he did in 1997.

Vote While You Float: An Astronaut Voting Story

With the excitement of getting to the polls on Election Day many people will have a hard time keeping their feet on the ground, but astronauts who vote literally have to strap themselves down so they don't float away.

Astronauts orbit the Earth at 17,000 miles per hour, but thanks to a bill passed by Texas legislatures in 1997 that put in place technical voting procedure for astronauts—nearly all of whom live in Texas—they also have the ability to vote from space!

For astronauts, the voting process starts a year before launch, when astronauts are able to select

which elections (local/state/federal) that they want to participate in while in space. Then, six months before the election, astronauts are provided with a standard form: the “Voter Registration and Absentee Ballot Request—Federal Post Card Application.”

“Space voting” was first used the same year it was implemented in 1997. NASA astronaut David Wolf became the first American to vote in space while on the Russian Mir Space Station. Current space station resident astronaut Shane Kimbrough is the most recent astronaut to take advantage of the opportunity.

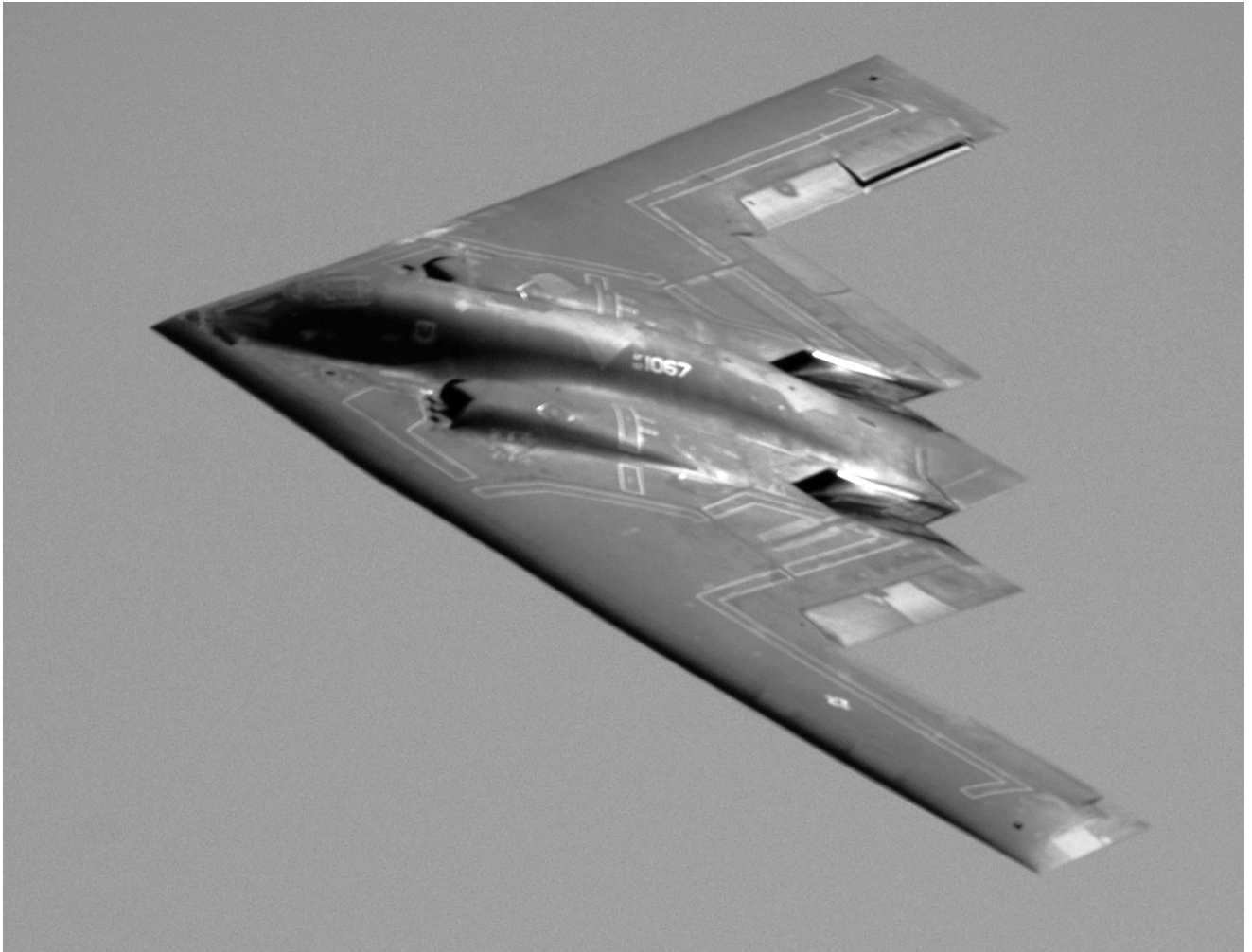
While astronauts don't have to wait in line for his ballot like the rest of us, there is one disadvantage to voting in space: they miss out on the highly coveted “I Voted” sticker.

Source: NASA. <https://nasa.tumblr.com/post/152733055774/vote-while-you-float-an-astronaut-voting-story>, accessed September 26, 2018.

Stealth Technologies

“Stealth technologies” include a range of tactics for undiscovered or undetectable travel. Though the term “stealth” is more often applied to air travel, stealth technology can be used on the ground as well. The ability to gather data without detection has been crucial to the post–World War II American military. The initial use of stealth technology applied to airplanes,

because the thin material that covers them is perfect for reflecting waves produced by radar. This discovery changed the game, considering the range of tactical abilities that planes possessed during World War II; jets served as a primary weapon. The ability to detect enemy aircraft as well as prevent detection of one's own planes became a priority. Once the use of radar to track aircraft materials became commonplace, methods for cloaking aerial machinery gained importance.



Northrop Grumman's B-2 Spirit, better known as the Stealth Bomber, was under development in the 1970s and 1980s. Though now a successful airplane design, the B-2 program's billion-dollar price tag made it controversial. (U.S. Department of Defense Visual Information Center)

Methods for decreasing an airplane's level of observability include shaping the plane in a way that radar waves reflected from it are angled away from radar equipment, and also covering the airplane in materials that absorb radar signals. These techniques meant that stealth planes did not have a rounded, aerodynamic shape but one composed of sharp angles, bringing the level of detection down from that of a plane to that of a bird. The only exception is when the aircraft banks or lands. These create a perfect ray of radar reflection straight to the detector.

The first undetectable aircraft in the United States was created by accident. The YB-49 Flying Wing was tested until 1948, when it crashed in the Mojave Desert. The plane went unnoticed by the then-current level of

radar detection, leaving observers shocked when it suddenly appeared overhead. The YB-49 never went into production, and it was eventually replaced by the Convair B-36, which did not have stealth technology.

Stealth technologies were first proposed as a tactic in 1953 for flying out of range of Soviet fighters, missiles, and radar. U.S. Air Force officer John Seaberg invited Bell Aircraft, Martin Aircraft, and Fairchild Engine and Airplane to submit ideas for accomplishing this task. When the Lockheed Aircraft Corporation heard of the competition, it began development despite the lack of request for it to do so. Lockheed's Clarence Kelly Johnson was asked to design the craft and incorporate executive John Carter's suggestions to eliminate landing gear and other unnecessary loads. Johnson

was an aeronautical engineer for Skunk Works, a division of Lockheed. His work on the Lockheed XF-104, an experimental jet with undetectable aerial technology, won the Collier Trophy in 1958.

The discovery that the size of a plane was not the only element that played into the amount of radar it reflected resulted in the Quail decoy drone. In 1961, it produced the same radar frequency as a much larger plane, which led to one of the first stealth technologies—simply flying planes higher to avoid radar detection. The techniques applied were dubbed “stealth” or “low observation” technology, but this eventually branched into “quantum stealth,” which worked on the basis of reflecting light rather than radar.

A short-term solution known as the U-2, or “Iron-Ball,” was developed at Lockheed in the 1960s. It was the first aircraft with radar-absorbing paint that successfully infiltrated Soviet territory until stronger radar detectors were developed. These more advanced radar detectors resulted in the U-2, piloted by Gary Powers, a spy doing reconnaissance over enemy lands, being shot down in 1962 with a barrage of missiles.

Even while Powers’s plane was crashing, another plane that could fly higher and faster was being developed with the idea of low observability. The A-12 would soon become the SR-71, able to reach speeds of Mach 3.3, or 2,215 miles per hour. This plane’s design was long and slim, with engines embedded in the wings and radar-absorbing material expanding past the paint surface. The political fallout from the Gary Powers event made it so that no more manned vessels were flown over Soviet territory. Instead, the A-12 was used to develop drones called D-21s that resembled the engine and wing of an A-12. These new developments collected data from over Soviet territory. The D-21 was launched from an A-12 with a high-resolution photographic camera and followed a predetermined course to provide information for ground troops. After four unsuccessful operational flights over the People’s Republic of China, however, the program was canceled in 1971.

In 1983, Lockheed Martin pioneered modern stealth aircraft by making planes faster, which gave radar detectors less time to pick up reflected frequencies. However, the faster a plane, the larger it had to become, meaning more surface area for radar to

bounce off of and negating any benefits that a speed increase might offer. The Tacit Blue Program was developed, declaring that with the proper stealth techniques, the ground game on the battlefield could be observed and reported on without detection—or fatalities.

Stealth technology has branched past working in the air to infiltrating troops on the ground. With quantum suits and parachutes, which bend and refract light, even fighters jumping from a plane or directly landing on the ground cannot be detected. When covering a human body, light-bending material only allows for sensors or human eyes to detect approximately 5 percent of a person’s shadow, leaving him or her 95 percent similar to the surroundings. Possibilities for this technology range from hiding the periscope of a submarine, invading an enemy camp without detection, assisting a sniper without cover, covering tanks so that they are not detected, and creating uniforms for troops to become invisible assailants.

Peg A. Lamphier

See also *Vol. 1, Sec. 3: Military Technology (Civil War); Machine/Gatling Gun; Morse Code; Repeating Rifle; Torpedo; Vol. 2, Sec. 3: Radar*

Further Reading

Graham, Richard H. 2015. *The Complete Book of the SR-71 Blackbird: The Illustrated Profile of Every Aircraft, Crew, and Breakthrough of the World’s Fastest Stealth Jet*. Minneapolis: Zenith Press.

Naylor, Sean. 2015. *Relentless Strike: The Secret History of Joint Special Operations Command*. New York: Macmillan Audio.

Superconductivity

The ability of some materials to exhibit zero electrical resistivity and magnetic flux expulsion is termed “superconductivity,” and those that display it are referred to as “superconductors.” Three American researchers best modeled the theory of superconductivity: John Bardeen, Leon Neil Cooper, and John Robert Schrieffer. They described the phenomenon in

terms of electron pairing, and theirs was the first microscopic theory of superconductivity. In 1972, the three men were awarded the Nobel Prize in Physics for their theory, more commonly referred to as the “BCS theory” according to their initials.

The definition of materials as superconductors is distinguished by two properties. One is that they offer no resistance to the passage of electrical current. The disappearance of electrical resistivity allows a current to circulate inside the material without wasting any energy. The other property of a superconductor is its impermeability to magnetic fields. Instead of penetrating it, a magnetic flux field remains at its surface. The latter characteristic is known as the “Meissner effect.” Materials actually transition into a superconducting state—and so suddenly that they look like they are going through a phase change.

The research into this state peaked with the discovery of high-critical-temperature superconductors. They differ from conventional superconductors, whose electrical resistance drops to zero when they are cooled below a critical temperature. Exposing a superconductor to any magnetic field automatically decreases its critical temperature, but the greater the strength of the magnetic field present, the colder the material needs to be to transition. If the strength of the magnetic field goes above a critical level, the material will fail to superconduct. Simply put, superconducting materials lose their ability to superconduct regardless of how cold they are if subject to powerful-enough magnetic fields.

This discovery led to the distinction of type I and type II superconductors. Type I has only one critical field and is completely expelled from the magnetic field. Type II has two critical fields that make it semi-permeable to the magnetic field. There are 30 pure metals that display zero electrical resistivity at low temperatures and can block magnetic fields. The BCS theory articulates what constitutes a conventional superconductor and the properties that contrast the two types of superconductors. The theory states that electrons get together in what it calls “Cooper pairs” within a superconductor instead of traveling independently. This is thought to be due to their frictionless flow. Transition temperatures for traditional superconductors are in the absolute zero range, but now, we can

also synthesize “high-temperature” superconductors that transition at warmer temperatures.

Superconductors have become incredibly lucrative due to their enormous variety of applications. One application where superconductors perform life-saving tasks is in biomagnetism. Doctors use it to observe what occurs inside the human body. By applying a strong superconductor magnetic field to the body, hydrogen atoms in the body’s water and fat molecules absorb the magnetic field’s energy, which then exits at a frequency that can be graphically translated by a computer. Superconductivity can also be used to make electricity generation more efficient so that innovations such as high-speed magnetic-levitation trains, ultra-high-speed computer chips, and high-capacity digital memory chips are possible. Electric generators produced with superconducting wire are more successful than basic generators composed of copper wire. These electric motors are practically infallible, and they are half the size of conventional generators. In the future, superconductors may be used in power plants that can significantly reduce the emission of carbon dioxide into the biosphere.

Leslie Botello

See also Magnetic Resonance Imaging (MRI); Military-Industrial Complex; *Vol. 3, Sec. 3: Wireless Communication*

Further Reading

Blundell, Stephen. 2009. *Superconductivity: A Very Short Introduction*. Oxford: Oxford University Press.

Tinkham, Michael. 1975. *Introduction to Superconductivity*. New York: McGraw-Hill.

Taussig, Helen (1898–1986)

Dr. Helen Brooke Taussig gained international acclaim for codeveloping the first successful “blue baby” operation for babies whose congenital heart defects cause their skin to turn blue from lack of oxygen. A Johns Hopkins pediatrician for most of her life and a leader among women in American medicine, Taussig saved countless lives by devising a method to correct infants’ heart defects. In addition to founding the field of

pediatric heart surgery, Taussig also played a major role in sounding the alarm regarding the use of thalidomide, a drug used by expectant mothers that caused birth defects in their children.

Born in Cambridge, Massachusetts, in 1898, Taussig was the youngest of four children who had the good fortune to come into a family that valued education highly. Her father, Frank W. Taussig, was an economist and professor at Harvard University who advised President Woodrow Wilson. Her mother, Edith Guild, had attended Radcliffe College. The family frequently socialized with the president and his wife, Edith Wilson.

Possibly the most influential factor in Taussig's drive to become a doctor was her mother's death from tuberculosis when Taussig was 11 years old. Taussig would overcome great odds to achieve her goal. Not only was she born a sickly child, but she also suffered from dyslexia; she later credited her father for helping her overcome this reading impairment. She did, however, always struggle with reading. Physician Helen Taussig founded the field of pediatric cardiology. She also played an important role in outlawing thalidomide, a drug prescribed to pregnant women for morning sickness that caused severe fetal birth defects. Taussig had an additional challenge that she later managed to parlay into a brilliant diagnostic tool; because she had lost her hearing thanks to childhood whooping cough, she had to rely on lipreading and hearing aids throughout the entire course of her career. Interestingly, her hearing impairment, rather than being a detriment, was actually considered a factor that contributed greatly to her success, thanks to her ability to differentiate between healthy and unhealthy heartbeats by touch.

Despite her many physical impediments, Taussig was an extraordinary student at her mother's alma mater, Radcliffe, where she spent her first two years of undergraduate study. She also became an excellent tennis player before transferring to the University of California, Berkeley, from which she graduated Phi Beta Kappa with an applied baccalaureate degree in 1921. From there she went on to Harvard, whose policy at the time prevented her from entering its then all-male medical school, although she was allowed to study histology on a noncredit basis. Taussig then went to Boston University, ultimately earning her

medical degree from Johns Hopkins University's School of Medicine in 1927.

Taussig served the first year of her internship at Johns Hopkins in the cardiology department, then two years interning in pediatrics. In 1930, she was put in charge of a heart clinic, where she began her research into heart defects. She was one of the first to use a system called fluoroscopy, then a relatively new x-ray technique.

Taussig soon zeroed in on a congenital heart condition called anoxemia, or "blue baby" syndrome. She used fluoroscopy to demonstrate that the infants who were afflicted with the condition suffered from leaky septums (the membrane that divides the heart's various compartments) and undersized arteries leading from the heart to the lungs. By applying the fluoroscopy method to examine sick babies' hearts, Taussig discovered links between abnormal hearts and birth defects, making the connection that a key component of infant mortality was that the ductus arteriosus, a blood vessel, closed at an inappropriate time.

At the same time, a heart surgeon in Boston, Dr. Robert Gross, had already created a surgical method to close the offending blood vessel when it stayed open unnecessarily in other situations; he suggested to Taussig that it might be feasible to construct such a method to create the missing blood vessel for blue babies.

In 1941, Taussig, inspired by Gross's insight, suggested the idea of the ductus operation to two coworkers at Hopkins—Alfred Blalock, a surgeon, and Vivien Thomas, a surgical technician. Taussig and Blalock experimented on dogs to perfect the operation, finally performing the operation on a one-year-old girl in 1944; the child survived for nine months after the operation. In 1945, Taussig and Blalock issued a report to the *Journal of the American Medical Association*, and their operation was soon being used worldwide.

Of perhaps equal importance to her contribution to the field of heart surgery was the connection that Taussig made after a 1962 tour through Europe. She found that an antinausea drug called thalidomide that was given to expectant mothers corresponded to disfiguring birth defects involving malformation of the limbs (phocomelia). Upon her return to the United States, Taussig sounded the alarm. Officials took her warnings seriously, and doctors stopped prescribing the drug.

In 1945, Taussig was awarded the Lasker Award for her blue baby operation, and in 1959, she was awarded a full professorship at Johns Hopkins—one of the very first women in Johns Hopkins's history to earn that distinction. She was elected president of the American Heart Association in 1965. She was also a recipient of the highest award given by the Johns Hopkins University School of Medicine, one of the first women to receive this honor.

Taussig remained at the Johns Hopkins Hospital until her retirement in 1963, not surprisingly working in the Children's Heart Clinic.

On May 20, 1986, Taussig was in a car accident near her home in Kennett Square, Pennsylvania, and died an hour later at Chester County Hospital. She was 87 years old. In keeping with her lifelong dedication to humanity and science, she donated her body to Johns Hopkins. Taussig never married and had no children.

Deborah L. Daughetee

See also Carson, Rachel; Yalow, Rosalyn Sussman; *Vol. 3, Sec. 2: Artificial Heart*

Further Reading

Stephens, Trent, and Rock Brynner. 2001. *Dark Remedy: The Impact of Thalidomide and Its Revival as a Vital Medicine*. New York: Basic Books.

Telephone Switching, Computerized

Before Erna Hoover, telephone switching was done by hand. A call would be made to a call center, where a human operator would direct the call to the correct receiver by virtue of a series of interconnected wires on a board. There were hundreds of jacks along the board, and the operator would have to search for the right cable for the correct jack. There were several employees at each call center routing the calls, but they could only handle so many at a time. This caused backups in the system. There were four main jacks shown on all the operators' switchboards, each for the main lines that connected calls. Once one of these lines was in use, a second call to that line could not be connected, so it was dropped.

To determine if the line was already in use, an operator would gently tap a cable plug against the rim of the jack. If it created a clanking noise, the line was in use. But this was an unsatisfactory way to handle calls. There were often jams where people's phone calls could not go through because the operators were busy dealing with a bombardment of calls. These large numbers of phone calls and delays needed to be addressed.

Erna Hoover contributed to the information technology world by creating a phone-switching system for phone traffic. Hoover was the daughter of a schoolteacher and a dentist. She was born on June 19, 1926, in Irvington, New Jersey, and sadly, her younger brother passed at the age of five from polio. Hoover was encouraged to learn, and she showed interest in the sciences at a young age. She earned her bachelor's degree at Wellesley College and then a PhD in philosophy and foundations of mathematics from Yale University.

Hoover was hired at Bell Laboratories, where she developed and patented the first computerized switchboard. This was a huge leap for the computer science industry, being a transition from electrical technology to computerized technology and paving the way for modern technology such as smartphones. Hoover's computerized switchboard involves a complex circuit board that allows phone calls to flow through more efficiently. Before this invention, the electronic system could only handle about 200,000 calls an hour, and if the calls came in too quickly, the system crashed and the calls would fail. Her invention allowed a larger number of phone calls to come in without causing the electronic server to freeze.

The computerization of the telephone switching board was a reliable alternative. This breakthrough led to a promotion for Hoover—one of the first women to be promoted to technical department head at Bell Laboratories.

Hoover is not mentioned often, but her contributions to computer science were crucial to jump-start the evolution of the telephone industry from the switchboard to the cell phone. In 2008, she was inducted to the National Inventors Hall of Fame and also given the Wellesley College Alumni Achievement award.

Anthony Bekdas

See also *Vol. 2, Sec. 2: Bell Telephone Laboratories; Vol. 3, Sec. 3: Smartphone and 3G Network*

Further Reading

“Software Switch.” 2001. *Technology Review* (Cambridge, Mass.) 104, no. 3: 104.

Thomas, Valerie (1943–)

Scientist Valerie Thomas patented the illusion transmitter, which transmits three-dimensional illusions of an object, in 1980. The transmitter was pioneering in 3-D technology and is still used today.

Born and raised in the state of Maryland, Thomas was very much interested in science as a child. At the age of eight, she witnessed her father tinker with the parts inside the family television and became curious about electronics and their functions. She read *The Boys’ First Book of Radio and Electronics*, which was filled with activities and projects, but her father was reluctant to help her despite his own interest in the subject. She attended an all-girls school where she was not encouraged to pursue science or math, though she did manage to take a physics course. At Morgan State University, she majored in physics and went to work at NASA after her graduation.

From 1964 to 1970, Thomas worked at NASA as a data analyst on the systems supporting satellite operations. After six years, she was put in charge of the team that helped create the Landsat program, which developed the longest-running technology that takes satellite images of Earth for applications in agriculture, geology, and education. Thomas became a team leader for the Large Area Crop Inventory Experiment (LACIE) in 1974, where she used space technology to help with wheat harvesting on a global basis. LACIE was a collaboration between the U.S. Department of Agriculture, NASA, and the National Oceanic and Atmospheric Administration (NOAA).

In 1976, she visited a scientific exhibit where there was a display that featured an illusion of a lightbulb that appeared lit even when the bulb was removed from its socket. This astounded her and led her to research the phenomenon. She discovered that two concave mirrors created the illusion. Flat mirrors have images that appear to be inside or behind them while concave mirrors can make images appear to be in front of them. At this moment, Thomas was sure that this

method of using concave mirrors could assist in her projects at NASA.

Thomas developed the illusion transmitter and received a patent for her invention in 1980. It paved the way for the birth of the modern 3-D imaging that we now see in television. This technology has also assisted the medical field; surgeons use her technology to help create 3-D images of the body. Thomas continued to work for NASA, rising through the ranks and becoming the project manager of the Space Physics Analysis Network (SPAN) in 1985 and associate chief of the Space Science Data Operations Office from 1986 to 1990. In 1990, SPAN was at the forefront of development of computer networking that led to today’s Internet. Thomas also participated in projects involving Halley’s comet, ozone research, and the Voyager spacecraft.

Valerie Thomas prided herself on giving back to community. Throughout her career, she spoke to countless groups of students from elementary to university level, as well as adult groups. She also served as a mentor in summer programs for students at the Goddard Space Flight Center. She also worked with organizations such as the National Technical Association (NTA) and Women in Science and Engineering (WISE), where she encouraged women and students of color to pursue careers in technology.

Valerie Thomas received the Goddard Space Flight Center Award of Merit and many more awards from NASA, including the Equal Opportunity Medal. Thomas retired from NASA in 1995, and in retirement, she mentors young people through the Science, Mathematics Aerospace Research and Technology Association and the National Technical Association.

Daniel Aparicio

See also Hamilton, Margaret; Mercury 13; National Aeronautics and Space Administration (NASA); Satellites and Space Probes; *Vol. 3, Sec. 3: Mars Rover Series*

Further Reading

Greene, B. 2005. *The Fabric of the Cosmos: Space, Time, and the Texture of Reality*. New York: Vintage Books.

Touch-Tone Phones

After rotary-dialing phones, the touch-tone phone was created. Many people have claimed to be the inventors of the touch-tone phone, but the Bell System is widely given the credit for commercializing it. Rotary-dial phones used the pulse dial system, which is a direct-current local loop circuit that is interrupted according to a set coding system for each transmitted digit and signal. The touch-tone telephone uses dual-tone, multifrequency signaling (DTMF), which is a telecommunication signaling system that uses voice frequency bands over phone lines. The Bell System trademarked this under the name “Touch-Tone” in 1963.

In 1962, Bell System displayed the touch-tone telephones to the general public to test out at the Seattle World’s Fair. The president of the United States, John F. Kennedy, even partook in the fair by keying “1964” on a touch-tone phone located in the Oval Office. The touch-tone phone was now ready to be sold commercially. On November 18, 1962, the first one was available to locals in Greenburg and Pittsburgh, Pennsylvania.

Through the advancement of touch-tone telephones, Western Electric created its ideal model, named the Western Electric 1500. It had 10 buttons. It was soon replaced with the Western Electric 2500 model, which had 12 buttons, adding the asterisk (*) and the pound (#) keys. John Karlin developed the now familiar four rows of three keys layout, to encourage accurate dialing.

Even though touch-tone phones were commercialized, the rotary-dial phone was still more common at the time. The biggest customers for the new phone in the beginning were businesses. Around 1979, the touch-tone phone was growing steadily in popularity but was not available in all areas. In the 1980s, its number of customers continued to grow, and by the 1990s, rotary-dial phones were no longer in the majority.

Today, touch-tone phones and the dual-tone, multifrequency signal continue to be used in the telecommunications world, but the smartphone is now on its way to replacing the traditional touch-tone phone.

Emma E. L. Burke

See also *Vol. 2, Sec. 1: American Telephone and Telegraph Company (AT&T); World’s Fairs; Vol. 2, Sec.*

2: Bell Telephone Laboratories; Vol. 3, Sec. 3: Smartphone and 3G Network

Further Reading

MacNeil, Jessica. 2017. “Tone Dialing Telephones Are Introduced, November 18, 1963.” EDN Network. November 18. <https://www.edn.com/electronics-blogs/edn-moments/4424443/Tone-dialing-telephones-are-introduced--November-18--1963>.
Raum, E. 2008. *The History of the Telephone*. Chicago, IL: Heinemann Library.

Trans-Alaska Pipeline

The Trans-Alaska Pipeline System, or TAPS for short, is a crude oil pipeline traveling across 800 miles of Alaskan terrain connecting the oil fields in Prudhoe Bay to the harbor in Valdez, Alaska. It is one of the largest pipeline systems in the world. The 1973 oil crisis, which caused significant increases in the price of oil, spurred the initiative to drill for the oil found in Prudhoe Bay in 1968.

Construction of the pipeline was successfully legally halted from 1970 to 1973 due to opposition from conservationists and Alaskan Native groups. Conservationists opposed the construction of a crude oil pipeline in Alaska because they viewed it as a threat to America’s last wilderness frontier. They also highly opposed the construction of the Dalton Highway, a road system that runs parallel to the pipeline and was built specifically to make the construction of the pipeline possible.

Conservationists opposed the construction of this highway because, although they viewed the pipeline as a threat to the wilderness, the pipeline was only designed to last 50 years before being dismantled, whereas the highway system would be permanent. The pipeline needed to be elevated due to environmental studies initiated by conservationists because of their concern about the effects on wildlife. In particular, they were extremely worried about caribou herds. They believed the effect would be similar to that on the American bison populations during the period of the Transcontinental Railroad.

After a series of environmental impact studies and reports, changes in the original design were required.

The most noticeable was the elevation of the pipeline—and even burying it when necessary—to allow wildlife to easily pass. Other changes included installing devices to scatter heat buildup around permafrost and bridges to allow the pipeline to cross rivers and streams without much disturbance.

Native groups fighting for the rights to their land eventually came to a settlement in October 1971, when President Richard Nixon signed the Alaska Native Claims Settlement Act. Under this act, Alaskan Natives surrendered their land and received \$962.5 million and 148.5 million acres of federal land. After all the opposition had been addressed and settled and the oil crisis of 1973 occurred, increasing support for the exploitation of Prudhoe Bay's oil reserves, construction finally began in March 1975.

The large project attracted thousands of men and women looking for employment, creating many “boom-towns” along the route of the pipeline. The work in this environment was cold, difficult, and required gruesome hours, which caused various issues. At least 32 workers are known to have died as a direct result of construction injuries alone. After years of work, the last weld was finished at Pump Station 3 near Atigun Pass on May 31, 1977. However, the first barrel of oil did not reach Valdez until well over the anticipated nine-day mark; it arrived at the harbor on July 28, 1977. This delay was due to mechanical issues that stalled production.

As time has passed, oil production in the area is declining, posing an issue for the future of the pipeline. Alyeska Pipeline Service Company, the private company that currently owns TAPS, plans on closing down all but four pumps as supplies continue to decrease. However, improvements to the pipeline that induce low-flow rates could extend the pipeline's life to as late as 2075. Under law, all traces of the pipeline are required to be removed from the land after oil

extraction is completed. Although plans are being continuously updated, there is currently no set date for this deconstruction.

The pipeline has delivered over 20 million barrels of oil to Valdez harbor. After oil was discovered on Alaska's North Slope in 1968, companies such as Humble Oil, British Petroleum (now BP PLC), and Atlantic Richfield Company had begun looking for an efficient way to transport these oil reserves to an ice-free port, leading to the construction of the pipeline. At a rate of four miles per hour, ensured by multiple pumping stations along the pipeline, a barrel of oil takes an average of nine days to complete the 800-mile journey to Prince William Sound.

Marissa N. Nahay

See also Vol. 2, Sec. 1: Transcontinental Railroad

Further Reading

- Andrasko, Kenneth, and Marcus Halevi. 1977. *Alaska Crude: Visions of the Last Frontier*. Boston: Little, Brown.
- Busenberg, George J. *Oil and Wilderness in Alaska: Natural Resources, Environmental Protection, and National Policy Dynamics*. Washington, D.C.: Georgetown University Press.
- Carmichael, Robert. 2011. “Trans-Alaska Pipeline.” In *Encyclopedia of Environmental Issues*, rev. ed., edited by Craig W. Allin, 1231–33. Pasadena, CA: Salem Press.
- McGrath, Ed. 1977. *Inside the Alaska Pipeline*. Millbrae, CA: Celestial Arts.
- United States Congress. Joint Economic Committee. 1972. *Natural Gas Regulation and the Trans-Alaska Pipeline: Hearings, Ninety-Second Congress, Second Session*. Washington, D.C.: U.S. Government Printing Office.

Primary Document: Bill to Reform the Trans-Alaska Pipeline System Authorization Act (1989)

The Trans-Alaska Pipeline has been a controversial issue since its beginnings in the 1970s. It was begun in 1974 after high oil prices made it economically feasible to extract the oil found in Prudhoe Bay in 1968. During construction, engineers faced many issues, often due to extreme weather conditions. By

the end of 1977, the pipeline had transported its first barrel of oil, and many notable incidents have occurred since, such as maintenance issues and malfunctions as well as vandalism and sabotage from outside opposition, all resulting in leakage from the pipeline. The following is a reform act retrieved from

the Library of Congress, which was proposed to the 101st Congress in 1989 in an effort to reform the Trans-Alaska Pipeline System Authorization Act.

Summary: H.R.3277—101st Congress (1989–1990)
Introduced in House (09/14/1989)

Trans-Alaska Pipeline System Reform Act of 1989—

Title I: Trans-Alaska Pipeline System Fund and Liability—Amends the Trans-Alaska Pipeline System Authorization Act to repeal the limits placed on liability for oil pollution damages caused by a holder of a pipeline right-of-way. Declares that certain liability provisions of the Act shall apply only to incidents occurring before the enactment of this Act.

Title II: Trans-Alaska Pipeline System Trust Fund—Establishes the Trans-Alaska Pipeline System Trust Fund (TAPS Trust Fund). Imposes a specified fee on oil transported through the trans-Alaska pipeline, and directs the Secretary of the Interior (the Secretary) to deposit such fees into the TAPS Trust Fund for the safe and environmentally sound operation of the trans-Alaska pipeline system.

Title III: Improvement of the Trans-Alaska Pipeline System—Establishes the Presidential Task Force on the Trans-Alaska Pipeline System to: (1) conduct a comprehensive audit and review of the trans-Alaska pipeline system; (2) make recommendations to the President and the Congress; (3) function as a permanent forum for improved oversight and enforcement of safety and environmental laws related to the trans-Alaska pipeline system; and (4) report to the President and the Congress regarding the audit results. Requires an annual report to the President and the Congress.

Establishes the Trans-Alaska Pipeline Terminal Advisory Council to: (1) assist trans-Alaska pipeline operators and government officials in developing policies, permits, and regulations relating to pipeline facilities that may effect public health and safety and the environment; and (2) serve as a forum for industrial users, owners, and operators of terminal facilities to work cooperatively with local residents.

Conditions use and operation of pipeline and terminal facilities along the trans-Alaska right-of-way upon cooperation with the Advisory Council through frequent consultation, attendance at meetings, and by granting the Council access to all facilities and

requested documents and information. Directs the Advisory Council to submit an annual status report to the Task Force, the Governor of Alaska, and the Congress.

Title IV: Alaska Oil Spill Recovery Institute—Directs the Secretary to establish the Alaska Oil Spill Recovery Institute to: (1) research and implement oil spill cleanup and prevention technology in the arctic and subarctic marine environment; and (2) assess the long-term Exxon Valdez oil spill's effects upon the Alaskan environment and natural resources.

Directs the Institute to establish a Scientific and Technical Committee to advise its Board of Directors. Directs the Institute to submit an annual status report to the Governor of Alaska and to the Congress.

Title V: Penalties—Amends the Outer Continental Shelf Lands Act to increase the civil penalty for non-compliance with such Act to \$20,000. Directs the Secretary to adjust such penalty on a triennial basis to reflect any increases in the Consumer Price Index. Directs the Secretary to assess a civil penalty for any oil discharges occurring at various transit stages related to the trans-Alaska pipeline. Imposes joint, several, and strict liability upon the owners of oil for the full amount of penalties assessed for an oil discharge (or any threat of one). Sets a minimum civil penalty amount of \$1,000 per barrel of oil discharged.

Title VI: Provisions Applicable to Alaska Natives—Amends the Alaska National Interest Lands Conservation Act to declare that solely for the purposes of bringing oil pollution liability claims, all Federal interest in lands validly selected but not yet conveyed to Alaska Native Corporations are deemed to have vested in the respective corporations as of March 23, 1989.

Amends Federal law to direct the Secretary to report to the Congress the results of a study of the issues of recovery of damages, contingency plans, and coordinated actions in the event of an oil spill in the Arctic Ocean.

Title VII: State Laws and Programs—Declares that this Act does not preempt or affect State laws, programs, and authorities regarding oil pollution liabilities. Directs the President to consult with the affected States regarding any oil discharges.

Source: U.S. Congress, House of Representatives. Available at: <https://www.congress.gov/bill/101st-congress/house-bill/3277>.

Transistor Radio

For the engineer, December 23, 1947, is immortalized as the day of the invention of the transistor. Others may point to 1954 and the release of the Regency TR-1 transistor radio, but for the businessperson, it was the breakthrough Japanese transistor radio in 1957 that had the greatest impact on American business. The Sony TR-63 would be the first “pocket-sized” portable radio. For a few years, American manufacturers had dominated the transistor radio market, since it was Bell Laboratories that gave us the transistor. The transistor radio, however, proved a perfect product for Japanese manufacturers. The Japanese Ministry of International Trade and Industry had been searching for new industries to develop in Japan after the war, and it helped finance a \$25,000 licensing agreement for Tokyo Telecommunications—which grew from 7 employees to become Sony Corporation (originally Tokyo Tsushin Kogyo) with over 500 employees. Sony used its advantage in low labor costs to release the smaller, lower-priced TR-63 transistor radio to the American market.

The 1906 development of the vacuum tube had moved electronics a huge step forward, but its size and reliability limited its product application. After World War II, America’s largest industrial laboratory, American Telephone and Telegraph’s Bell Laboratories, started a research project to develop a better electronic switch and amplifier for the telephone. Following the goal-oriented research and development methods of Thomas Edison, this was an extension of earlier research on semiconductors. In 1947, the transistor came into being; the team of Bill Shockley, John Bardeen, and Walter Brattain would win a 1956 Nobel Prize for their work. Companies around the world wanted to develop products in which the new tech could be used. In 1954, Texas Instruments developed the first silicon transistor, which was picked up for military applications, but it wanted more profitable, commercial applications. A year earlier, Masaru Ibuka, cofounder of Sony, had traveled to the United States to study transistors and was able to purchase a license to produce them. Ibuka started a commercial product development team back in Japan

with his partner, physicist Akio Morita. Japan would emulate this strategy of buying or copying basic research to invest into product development in many industries.

Texas Instruments teamed up with Industrial Development Engineering Associates and Regency Electronics to manufacture the Regency TR-1, the first transistor radio, in 1954. The TR-1 was designed to be as small as possible, based on a market analysis of a 20-million-unit market. The TR-1 struggled with quality problems and a price tag of \$49.95 (over \$360 in today’s dollars). Yet, sales reached 100,000 per year. Raytheon’s 8-TP-1 and Sony’s TR-55 entered the market in 1955. The Raytheon radio had better quality and reliability but was larger and carried an \$80 price tag. Sony’s had the lowest price at \$39.99 and was the smallest; still, the sales remained around 100,000. The radio was not considered pocket-size yet. The Sony effort was a total failure, but as was typical of the Japanese product development model, it learned from its mistakes and introduced a new product quickly. The Sony TR-55 also lacked advertising because Sony was still a small company with limited capital. It advertised the product only in trade magazines. Sony looked to miniaturize its product and advertise more.

In 1957, it introduced the TR-63 to Americans, cracking the transistor radio market wide open. It measured roughly 4.5 by 3 by 2.5 inches and used a nine-volt battery. The company quickly got the price down to under \$25, which opened up more market. By 1962, the price was \$15. Sony advertised the radio as pocket-size, although it was a very uncomfortable fit. Sony also hired an advertising agency, and a cartoon character named “Atchan” was created to advertise the radio. Market success and low Japanese labor costs quickly brought competitors such as Toshiba and Sharp into the business. The transistor was the root of these electronic giants of today.

Many cultural forces combined to make the transistor radio a major commercial success. These included the huge youthful population segment (baby boomers), high disposable income after World War II, and the growing popularity of rock ‘n’ roll music. In addition, the Japanese learned marketing. They started to produce colorful and novel plastic cases to attract the youth market. They also produced radios with

corporate logos for the business promotional market. In many ways, the transistor radio business taught the Japanese how to be successful with products in the United States. The Japanese applied this simple business model to overtake market after market in the United States, but by the late 1960s, production had left Japan for Hong Kong because of lower labor costs there. Today, China is the major producer of transistor radios, although American Zenith held on to the upper end of the market for years. The transistor radio success inspired the Japanese to move into the American market with other products, including cars. The transistor radio today remains the most popular communications device in history, with estimates that 7 billion were produced.

Quentin R. Skrabec

See also *Vol. 2, Sec. 2:* Bell Telephone Laboratories; Galvin, Paul Vincent; *Vol. 3, Sec. 2:* Satellite Radio

Further Reading

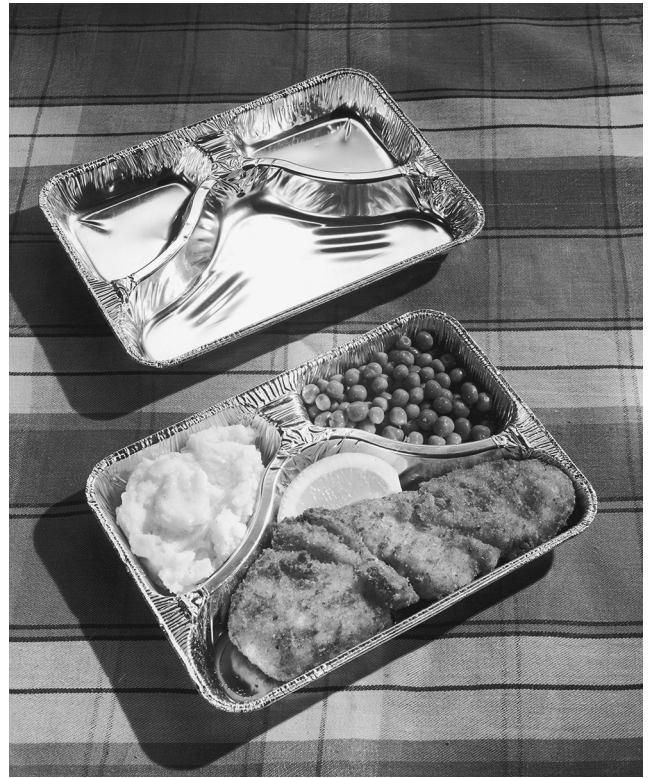
Morita, Akio, and Sony Corporation. 1994. *Made in Japan*. New York: HarperCollins.

Nathan, John. 1999. *Sony: The Private Life*. New York: Houghton Mifflin.

Schiffer, Michael Brian. 1991. *The Portable Radio in American Life*. Tucson: University of Arizona Press.

TV Dinner

A TV dinner is a prepackaged, ready-made meal that can be reheated in the microwave or conventional oven. It usually consists of an individual portion of some type of meat, a vegetable and/or starch such as potatoes or rice, and sometimes a dessert. The idea for these meals came from a company called Maxson Food Systems that began making meals that could be reheated during airline flights in 1945. Swanson was the first to market frozen meals to the nation in 1954. With a surplus of turkey around the Thanksgiving holiday in 1953, Swanson decided to sell a frozen Thanksgiving meal and market it as a “TV dinner.” The meal was packaged in the same tray it would be reheated in.



In the 1950s and 1960s TV dinners were marketed to American women, many of whom enjoyed increasing disposable income and job opportunities, as labor-saving convenience products. (Stringer/Hulton Archive/Getty Images)

The TV dinner became immensely successful because of its convenience and because Swanson also cleverly linked its frozen dinners to a recently popular invention—television. TV dinners were introduced when family life was changing. More women were working for wages and looked for ways to save time on food preparation. These meals were also popular with bachelors who did not want to cook. Rising divorce rates in the 1970s and 1980s encouraged companies to market frozen dinners to single men.

Emma E. L. Burke

See also *Vol. 2, Sec. 1:* Food Preservation; Margarine; *Vol. 2, Sec. 2:* Blender; *Vol. 2, Sec. 3:* Microwave Oven

Further Reading

Hine, Thomas. 1986. *Populuxe: The Look and Life of American in the '50s and '60s, from Tailfins and TV Dinners to Barbie Dolls and Fallout Shelters*. New York: Knopf.

Unimate/Industrial Robot

An unimate or industrial robot is an automated machine capable of completing factory tasks with mathematical precision. Its abilities range from welding metals to picking and placing parts of circuits, and more. These robots move on one or two axes, allowing them to handle specific operations with ease and rigor. The first known industrial robot was the unimate—a mechanical “arm” that welded metals on automobiles with more exactness and safety than human workers at the time. The device could effortlessly transfer all kinds of objects and material to their necessary destinations and thus guarantee that no more factory workers would be harmed in completing such tasks.

In 1956, American engineer George Devol of General Motors and business associate Joseph Engelberger originally designed the unimate as a literal mechanical arm. The unimate revolutionized the production industry, as it was the world’s first industrial robot. The device was a mechanical arm designed to complete factory tasks more easily and efficiently than the average worker. This robot was also designed to weld metal auto parts and die castings with more precision and safety; the job was hazardous for workers, as it released toxic fumes.

The machine weighs up to 4,000 pounds and consists of two large, connected boxes joined to a long arm. The robot is easily programmed and controlled. Today, the robot is even used to design other types of industrial robots. The unimate has six programmable axes of motility that allow it to adapt to manipulating many different kinds of metal parts. The unimate robot vastly increased production amounts and speed beyond what humans can do by hand.

Some of these industrial robots complete certain strategic actions repeatedly; these are called “repetitive actions.” They perform with extreme precision. Such robots require highly particular motion sensors to carry out their tasks and are programmed for a specific velocity and acceleration.

In 1962 George Devol and Joseph Engelberger founded Unimation, the world’s first robotics company. Victor Scheinman, from Stanford University, invented the Stanford arm in 1969—a multiaxis version of a unimate. His vision was to replace human

factory workers entirely. By the late 1970s, many U.S. industries had adopted the newer industrial robots, including General Motors, which had originally invented the unimate. The market for industrial robots erupted, and companies were established to appeal to potential buyers. While the robotic economy rose, Unimation, was sold to Westinghouse Electric Corporation for the price of \$107 million. Later, Westinghouse sold Unimation to Staubli Faverges of France in 1988. But it was mainly Japanese companies that excelled in the robotic market, producing the highest quality robots.

Rubayia D. Manju

See also *Vol. 1, Sec. 2: Lowell Mill System; Vol. 2, Sec. 2: General Motors (GM); Vol. 3, Sec. 2: Robotic Surgery*

Further Reading

- Jordan, John M. 2016. *Robots*. The MIT Press Essential Knowledge Series. Cambridge, MA: The MIT Press
- Nof, Shimon Y. 1999. *Handbook of Industrial Robotics*. 2nd ed. New York: John Wiley & Sons.

Universal Automatic Computer (UNIVAC)

The Universal Automatic Computer (UNIVAC) was one of the first commercial computers ever built in the United States. Before that, computers were created as one-off products to be used for particular jobs, and then the UNIVAC changed the game. The UNIVAC was intended to solve business and administrative problems, but its ability to collect and analyze data made it useful to its first buyer, the U.S. Census Bureau.

The UNIVAC had 1,000 words of retention, and each word had a number of decimal digits. It could handle numbers, equations, and problems that punch card machines could not. The UNIVAC also computed data regarding research and expenses. It was a business computer ahead of its time that paved the way for the laptops and computers that we use today.

The Universal Automatic Computer was created by Drs. John Presper Eckert and John Mauchly, the

inventors of the Electronic Numerical Integrator and Computer (ENIAC). After they left the University of Pennsylvania Engineering School, the U.S. Census Bureau asked them to create a machine that could help track the rapid increase of population at the end of the 1940s. The Universal Automatic Computer was essentially an upgrade or improved version of the Electronic Numerical Integrator and Computer.

The first UNIVAC cost approximately a million dollars to manufacture and was funded by investors such as Remington Rand Inc. In 1951, the first UNIVAC computer was delivered to the U.S. Census Bureau. The Prudential Insurance Company was the first commercial customer for the new computer.

The UNIVAC also helped pave the way to the era of big computer equipment common in the 1960s and 1970s. The computer was too costly for even major universities at the time, so it was most often bought by governmental organizations or corporations for business and administration purposes. In 1952, the television broadcast channel CBS used the UNIVAC to successfully predict the results of the U.S. presidential election in advance, claiming that Eisenhower would win. This achievement raised public awareness of technology and computers. The UNIVAC revolutionized the way we predict the patterns of many things and how we use technology and analyze data. The Universal Automatic Computer was also used to tabulate the 1950 U.S. population census as well as the 1954 economic census.

Fewer than 50 UNIVAC computers were made. Each one was about 25 by 50 feet in area and weighed around 16,000 pounds. Because the UNIVAC was difficult to manufacture, it was nearly impossible to keep up with the demand for its use. It was the main competition for IBM computers, which were easier to produce but were slower in performance.

The original UNIVAC is now displayed at the Smithsonian Institution. The UNIVAC computer foreshadowed our reliance on software today. It revolutionized technology and began the computer industry we now find indispensable.

Rosanne Welch

See also IBM 360 Computer; *Vol. 3, Sec. 2*: Apple II; IBM Personal Computer; Personal Computer (PC); *Vol. 3, Sec. 3*: Linux

Further Reading

- Lundstorm, David E. 1990. *A Few Good Men from Univac*. History of Computing. Cambridge, MA: The MIT Press.
- Stern, Nancy B. 1981. *From Eniac to Univac: An Appraisal of the Eckert-Mauchly Computers*. Bedford, MA: Digital Press.

Vaccines

A vaccine is a biological agent or preparation that, when introduced into a host, produces an immune response in the host. Vaccines are largely preventative, though medical science is exploring the possibility of therapeutic vaccines for diseases like cancer.

The word “vaccine” originally meant the introduction of cowpox disease into the human body to produce immunity to smallpox. Over time, it came to be applied to other methods of disease control that worked with the same principle in mind—namely to artificially induce immunity by inserting a version of the organism that works to prevent or ameliorate its dangerous symptoms.

The smallpox vaccine was introduced by Englishman Edward Jenner in 1798. Smallpox is an infectious disease of the blood system, nose, and mouth whose distinguishing characteristics are extensive skin rashes and blisters. It is called “smallpox” to distinguish it from the “great pox” known now as syphilis—which equally terrorized families at the time. During the 18th century, the mortality rate from this disease alone was roughly 35 percent, meaning that one in three people infected with smallpox died. Mortality was even higher among infants and young children. Those who did not die from it were typically impacted by lifelong symptoms such as blindness, pitted or “pockmarked” skin, and an overall weak condition. Smallpox is sometimes known by its Latin name “*variola*”; hence, the term “variolation” can be used interchangeably with “inoculation.”

By the 18th century, the treatment and eradication of smallpox became one of the humanitarian and “enlightened” measures of educated people on both sides of the Atlantic. The preventative possibilities of inoculation prompted many supporters both inside and

outside the medical community, including Enlightenment writers such as Voltaire and America's Benjamin Franklin, who lost one of his children to smallpox, to advocate broader use of the method.

Inoculation was not without its dangers. While it was known that infecting a person with a weakened form of the disease could provide immunity to smallpox, it was unknown precisely how this happened, and further, the procedure could cause harm or death in inexperienced hands. Examples abounded of patients dying after being inoculated, or the inoculated setting off an epidemic of smallpox within their local community. With these observations in mind and coupled with the fact that inoculation's greatest supporters were often progressive or "enlightened" people, their adversaries among clergy, doctors, and civil officials were deeply wary of the method if not outright hostile to it.

The first documented instance of inoculation in the 13 colonies occurred in Boston, Massachusetts, in 1721. The Puritan minister Cotton Mather had learned about the method over a decade before from one of his slaves, and he researched it. When an epidemic of smallpox broke out in 1721, he advocated for local residents to be inoculated. Mather assisted Boston physician Zabdiel Boylston, who inoculated nearly 300 in the city, with only six deaths. The 1721 outbreak in Boston was a watershed moment for inoculation in the Americas, as it demonstrated the preventative possibilities of inoculation and eased the consciences of some religious objectors.

By the 1840s, it had been determined that immunity gained from smallpox vaccination could weaken over time, meaning that each person needed to be periodically revaccinated to remain protected. The question of maintaining consistent and periodic vaccinations came to the forefront, and compulsory vaccination became a matter of intense social and political debate by the middle of the 19th century. Great Britain passed mandatory infant vaccination in 1853, with a number of continental European powers following suit. As the situation in the United States was more decentralized, the question of compulsory vaccination was left up to state legislatures. Massachusetts was the first to pass such measures for infants as far back as 1809. This type of legislation was enforced by requiring students entering public schools to provide certificates of vaccination.

By the first decades of the 20th century, 5 states prohibited compulsory vaccination outright (Arizona, Utah, Minnesota, and North Dakota), while 10 states and the District of Columbia had a system for compulsory vaccination in place. Vaccine policy was a battleground between medical reformers desiring to "uphold the greater good of the community" and those fearful that compulsion stood in the way of their civil right to freedom of conscience. This matter was only partially resolved in the landmark Supreme Court case of *Jacobson v. Massachusetts* (1905), where the ruling was in favor of state legislatures and compulsory vaccination laws based on the principle that individual rights sometimes needed to be curbed by the power of the state to protect the common welfare. *Zucht v. King* (1922) upheld this decision with regard to vaccine certificates and admission into schools.

While the term "vaccine" initially referred to the smallpox vaccine, French scientist Louis Pasteur successfully proposed in 1881 that the term also be applied to the latest advances in inoculation against other diseases, such as anthrax and rabies, as homage to the pioneering work of Edward Jenner. While Jenner's vaccine substituted another, less violent disease as a preventative measure, the new generation of vaccines created during the late 19th century used a specimen of the disease itself weakened in a laboratory environment. This advance allowed a number of new vaccines to be developed over the turn of the 20th century: tetanus (1890), typhoid fever (1896), diphtheria (1921), and pertussis or "whooping cough" (1927).

The development of medicines in professional laboratories also increased the role of pharmaceutical companies in the research, production, and distribution of vaccines. The Second World War, which sent American soldiers to fight in varied environments across the world, also aided in the development of new vaccines. The military developed the first vaccine for influenza during the 1940s, where researchers gained experience that they applied to creating new vaccines during the postwar period. One of these was Jonas Salk, who developed the polio vaccine in 1952. American physicians Thomas Chalmers Peebles (1921–2010) and John Franklin Enders (1897–1985) worked on isolating diseases and developed a vaccine for measles at Children's Hospital in Boston in 1963. Enders

is known as the “Father of Modern Vaccines” because of his pioneering work isolating the polio strain, for which he shared the Nobel Prize in 1954.

The most prolific vaccine researcher of the 20th century was the American microbiologist Maurice Hilleman (1919–2005). During the span of a long career in medicine, he created over 36 vaccines, of which 8 are part of the list of 14 vaccines currently recommended for every person. As a researcher at E. R. Squibb & Sons, a pharmaceutical company headquartered in New York City, he developed a vaccine against Japanese B encephalitis that greatly aided the treatment of soldiers fighting in the Pacific Theatre during the Second World War. As head of virus and cell biology research at Merck & Co. from 1957 to 1984, Hilleman researched a vaccine against mumps, measles, hepatitis B, chicken pox, and pneumonia, among others. Hilleman and his associates developed the MMR vaccine in 1971, which combines measles, mumps, and rubella in one single shot.

The global development and distribution of vaccines is a major political and humanitarian effort that gained momentum after 1945. The World Health Organization, an agency of the United Nations founded in 1948, has a significant role in the development of vaccines and their administration. It targeted smallpox for worldwide eradication, which ended successfully in the late 1970s due in large part to greater access to vaccines.

Vaccines continued to be developed into the 21st century, often in response to challenges brought by resurgent or emerging diseases. These include rotavirus (1998), human papillomavirus (2006), and enterovirus 71 or “hand, foot, and mouth disease” (2013). In 2003, the first nasal vaccine for influenza was approved in the United States. The future of vaccines may hinge on the fact that they only prevent a small number of diseases at present. Traditional vaccines, which use either weakened or dead versions of the disease organism, cannot protect against certain mutations or changes in the disease. “Third generation” vaccines, which make use of genetically engineered bacterial DNA inserted into the cells of the body to create new antigens to combat pathogens, will be the next generation of vaccinations. Currently, experiments with DNA vaccines are being applied to West Nile virus and bird flu variants. The ethical questions behind altering DNA

and how such vaccines will be developed, distributed, and marketed remain a matter for future debate.

However, traditional vaccines continue to be a source of conflict in American society. Part of this is the legacy of the anti-compulsory-vaccination debates of the late 19th and early 20th centuries that uphold vaccination as a matter of individual conscience. Some express concerns over the “commodification” of vaccines by companies looking to profit rather than maintaining a suitable safety margin against potential side effects. The highly discredited link between the MMR vaccine and autism proposed in a 1998 medical article (later fully retracted in 2010) still remains the foundation for a new movement of anti-vaccination literature, despite the utter lack of evidence of any such link. Public health officials and parents who do vaccinate their children point out that parents who choose to not vaccinate in the face of overwhelming evidence of vaccination safety endanger not only their own children but all children too young to be vaccinated.

Sean P. Phillips

See also Polio Vaccine; Vaccines

Further Reading

- Colgrove, James. 2006. *State of Immunity: The Politics of Vaccination in Twentieth-Century America*. Berkeley and Los Angeles: University of California Press.
- Fenn, Elizabeth A. 2010. *Pox Americana: The Great Smallpox Epidemic of 1775–82*. New York: Hill and Wang.
- Finger, Simon. 2012. *The Contagious City: The Politics of Public Health in Early Philadelphia*. Ithaca, NY: Cornell University Press.

Vaughan, Dorothy (1910–2008)

Mathematician Dorothy Vaughan was also the first African American woman to supervise a group of employees at the National Advisory Committee for Aeronautics’s (NACA) Langley unit.

Vaughan was born on September 20, 1910, in Kansas City, Missouri. Her family moved from Missouri to West Virginia, where she graduated from Beechhurst



Dorothy Vaughan, Leslie Hunter, and Vivian Adair in 1950, working as mathematics calculators for Langley Research Center, a precursor to NASA. Vaughan was Langley's first black, female supervisor. (Smith Collection/Gado/Getty Images)

High School in 1925. Her good grades earned her a full-tuition scholarship to Wilberforce University, a historically black college in Wilberforce, Ohio. She graduated with a bachelor of arts in mathematics at age 19 in 1929.

The Great Depression also hit the nation in 1929. Therefore, although her professors at Wilberforce recommended her for graduate studies in mathematics at Howard University, she opted to earn a degree in education and become a teacher, as it was a stable career for black women with college degrees. Her income allowed her family to survive the depression. In 1932, she married Howard S. Vaughan Jr., with whom she had six children. She taught mathematics at Robert Russa Moton High School in Farmville, Virginia. In 1941, President Franklin Roosevelt signed Executive Order 8802 that prohibited racial discrimination in the national defense industry. Roosevelt believed the order would

ensure that the entire American effort, regardless of a person's race, was geared toward World War II, a war he believed the United States would win in the air.

Two years later, Vaughan applied to NACA's aeronautical laboratory in Langley, Virginia. The laboratory required mathematicians, or "computers," to meet the increasing demand for processing aeronautical data and preferred to hire women because they could be paid lower wages than men. The new "colored" mathematician hires were assigned to the segregated West Area Computing unit. These women's contributions spanned every area of research at Langley.

In 1949, Dorothy Vaughan was promoted to be the supervisor of the West Area Computing unit, which had been previously headed by white women. The West Area Computers continued as an all-black, all-female group. Members were required to use segregated bathrooms and eat in segregated cafeterias.

Vaughan was NACA's first black supervisor and one of the few women supervisors there. She was a strong advocate for the women not only in West Computing but in the entire NACA organization. Department heads and the engineers put stock in her recommendations regarding which women were best for particular projects.

Noted physicist and mathematician Katherine Johnson also worked for the West End Computers branch of NACA. Johnson was recognized as particularly skilled in computing celestial navigation, rocket trajectory calculations, and calculations for backup plans for Apollo and Space Shuttle program flights. She also contributed to the calculations for Mars missions.

Mathematician Mary Jackson also worked with the West End Computers, and in 1958, when NASA desegregated, she became the agency's first female black engineer.

Vaughan remained the head for West Computing until 1958, when NACA reformed into the National Aeronautics and Space Administration (NASA). Segregation in NASA was abolished in 1958, which meant the closing of the West Computing unit and all other segregated units. Dorothy and the women in West Computing joined the new Analysis and Computation Division (ACD). In 1961, Vaughan transferred to digital computing as NASA phased out human computers with electronic computers. She mastered programming in FORTRAN and made contributions to the Scout Launch Vehicle Program. Scout missiles were designed as launch vehicles for satellites and proved so successful that they were used from 1964 to 1991.

She retired from NASA in 1971 and died in 2008 in Hampton, Virginia. She was 98 years old. In her retirement, she had volunteered as a missionary for the African Methodist Episcopal (AME) Church.

Vaughan was largely unknown until the 2016 publication of *Hidden Figures*, a book about the black female NASA mathematicians. A film of the same name that year brought further public attention to Vaughan's importance.

Martha Njuguna

See also Brown, Marie Van Brittan; Carson, Rachel; Hamilton, Margaret; Hopper, Grace; Jackson, Mary

Winston; Lacks, Henrietta; McClintock, Barbara; National Aeronautics and Space Administration (NASA); Ochoa, Ellen; Rocket Girls of JPL; Taussig, Helen; Thomas, Valerie; *Vol. 2, Sec. 3*: Thomas, Vivien Theodore; *Vol. 3, Sec. 3*: Jemison, Mae

Further Reading

Shetterly, Margot. 2016. *Hidden Figures: The American Dream and the Untold Story of the Black Women Mathematicians Who Helped Win the Space Race*. New York: HarperCollins.

Vocoder

Invented at Bell Labs, the vocoder is a mechanism created to analyze and synthesize the human voice and translate it to an audio data compression. This can be used to encrypt, transform, and compress voices. The vocoder is known as a part of the "voice codec," another term for "speech coding." The mechanism was first developed in 1928 by an engineer named Homer Dudley. It was first presented to the public at the AT&T Building at the 1939 World's Fair as a machine for producing recognizable speech over a distance.

Radio companies were interested in vocoders because they could compress audio data to reduce transmission bandwidth. The way the vocoder works is, it takes in input from a multiband filter and passes it through an envelope filter, which takes high-frequency signals and produces an output. From there, the output is sent to a decoder. The decoder then takes the applied settings from the filter and resynthesizes the sound.

The vocoder was used as a communication method during World War II, but it is now used mainly in electronic music.

Kim Nguyen

See also *Vol. 2, Sec. 2*: Bell Telephone Laboratories

Further Reading

Tompkins, Dave. 2011. *How to Wreck a Nice Beach: The Vocoder from World War II to Hip Hop: the Machine Speaks*. n.p.: Stop Smiling Media.

Voyager Spacecraft

As of 2017, the Voyager mission was the most scientifically productive space investigation yet launched by the National Aeronautics and Space Administration (NASA). Both the *Voyager 1* and *Voyager 2* spacecraft (unmanned probes) sent back comparatively close-up images of planets and moons in the solar system that could previously be seen only as specks of light on the most powerful Earth-based telescopes. After the conclusion of the mission, the probes darted in opposite directions toward the edges of the solar system on their way to interstellar space.

The Voyager spacecraft were nearly identical. Each had a puck-shaped frame about 6 feet in diameter, 10 instruments for gathering scientific data, a communications antenna for sending data to Earth, a computer to run on-board systems, a high-gain dish about 12 feet in diameter for receiving command signals from Earth, a power generator that harnessed electricity from heat given off by several kilograms of plutonium-238, and various types of cameras. Each craft carried an identical gold-plated record of sounds and images of Earth as well as a map showing Earth's location. Scientists hoped that aliens would one day find these, perhaps millions of years in the future, and learn about Earth.

Both probes were launched from Cape Canaveral in 1977, but *Voyager 2* was launched two weeks before *Voyager 1*. NASA chose the names of the probes based on the order that they would reach Jupiter and Saturn. *Voyager 1* followed a shorter and faster route and passed *Voyager 2* in the asteroid belt between the orbits of Mars and Jupiter.

Voyager 1 reached Jupiter in 1979 and sent back clear images of the planet and its moons. Some of the most significant discoveries included volcanic eruptions on the moon Io, linear features on the moon Europa, and a dark ring within the rings of the planet. *Voyager 1* then used the gravity of Jupiter to propel itself toward Saturn.

Voyager 2 reached Jupiter four months later. Many of the images gathered by *Voyager 2* were similar to those gathered by *Voyager 1*. For example, *Voyager 2* also observed the volcanic activity on Io, although in much greater detail. *Voyager 2* made one significant new

discovery when it found a satellite (a small moon later named Adrastea) close to Jupiter's rings. *Voyager 2* then used a gravitation assist to slingshot toward Saturn.

Voyager 1 reached Saturn in 1980 and sent back images of the planet and its moons. *Voyager 1* revealed that the planet's rings were much more complex than previously known. Having completed its mission, *Voyager 1* used the moon Titan's gravitational pull to propel itself toward the edge of the solar system. *Voyager 2* arrived at Saturn a few months later and sent images that corroborated *Voyager 1*'s data.

Since the two outer planets were in a certain alignment that would not occur again for another 150 years, NASA decided to extend *Voyager 2*'s mission. *Voyager 2* reached Uranus in 1986 and Neptune in 1989. It discovered 10 new moons orbiting Uranus. And, it documented giant storm systems on Neptune, a dark spot on the planet, and six new moons. Finally, with a gravity assist from Neptune, *Voyager 2* propelled itself toward the edge of the solar system.

Before the Voyager mission, NASA had launched other long-range probes. However, none of them had remained in operation long after their missions were completed. In contrast, the Voyager craft continued to transmit scientific data from the edge of the solar system for decades. In fact, instrument readings on board *Voyager 1* in 2012 reported a significant drop in the number of solar wind particles and a simultaneous rise in interstellar cosmic rays, which convinced scientists that the probe had left the solar system and entered interstellar space; it was the first documented case of a man-made object reaching this milestone. Estimates of the dates of demise of the on-board battery power of both probes range from 2020 to 2030, about half a century after they left Earth.

Rolando Avila

See also National Aeronautics and Space Administration (NASA); *Vol. 3, Sec. 3: Hubble Space Telescope*

Further Reading

Benson, Michael. 2003. *Beyond Visions of the Interplanetary Probes*. New York: H. N. Abrams.

Harwood, William, and Stephen P. Maran. 2001. *Space Odyssey: Voyaging Through the Cosmos*. Washington, D.C.: National Geographic.

Wise, Brownie (1913–1992)

Brownie Wise made her mark on history by developing innovative new methods of marketing and selling products and motivating sales teams at a time when women working for wages was practically unheard of. She was the first woman to be featured on the cover of *Businessweek* thanks to the at-home sales model she created for the Tupperware Home Parties company, which many other companies, including Avon and Mary Kay Cosmetics, use today.

Born in 1913, in Buford, Georgia, Brownie Mae Humphrey's working parents divorced when she was young. Because her mother's job as an organizer for a hatmaker's union required her to travel, Wise spent much of her childhood in Atlanta, Georgia, with an aunt.

Wise's leadership abilities became evident when she was 14 and had begun giving speeches to the union members her mother had been sent to meet. She left school in eighth grade to accompany her mother on business trips. At the age of 18, Wise attended a YMCA camp for career-minded girls in hopes of becoming a writer or an illustrator.

Wise's artistic ambitions were rewarded in Dallas, Texas, in 1936 when she won a contest to paint a mural at the Texas Centennial. While there, she met Robert W. Wise, who had been sent to oversee the Ford Motor Company's exhibit. The couple married in 1936 and relocated to Detroit, where their only child, Jerry Wise, was born in 1938.

Though Wise was home with her child, she did manage to realize her other ambition—to write professionally—by contributing to a *Detroit News* column in which submitters wrote about their lives under fancifully assumed pen names. The lovingly rendered details of Wise's literary double, "Hibiscus," bore no resemblance to Wise's own self; sadly, what they *did* reveal was a woman whose idealized depictions of a loving husband and genteel childhood spent at her grandmother's Southern mansion provided an escape from the reality of her working-class origins and unhappy marriage to a violent alcoholic.

When the Wises divorced in 1942, Brownie worked two jobs—one as a saleswoman in a clothing shop, the other as a secretary. She also began selling for Stanley Home Products, one of the originators of

the so-called home party demonstrations, and Wise soon became a top seller.

In the late 1940s, Tupperware, which was already being sold in department stores, appeared on Wise's radar. Thinking its need to be "burped" made it the perfect home demonstration product, Wise left Stanley to start her own company: Tupperware Patio Parties.

In 1948, Wise phoned Earl Tupper (1907–1983), Tupperware Products's founder, and informed him of her company's success selling Tupperware. Tupper, who had already attempted his own unsuccessful version of a home party division, soon joined forces with Wise, and in 1950, Wise, her son, and her mother left for Florida, where Tupper appointed Wise vice president. Based on Wise's plan, Tupperware was withdrawn from retail stores in the early 1950s, and home selling became its primary market.

Wise then began empowering women in the home. The 1950s were a time when women were struggling to find a balance between work and family. So, Wise created Tupperware Home Parties Inc., and turned homemakers into entrepreneurs. At the lowest level were the dealers, who demonstrated and sold the product at home parties. Successful dealers were able to move up to the manager level, where they would oversee and train their own group of dealers.

In a time when women did not receive much recognition, Wise also developed a newsletter that celebrated top dealers. She held a yearly convention called the Jubilee where housewives could escape their domestic lives and celebrate their success, learn new sales techniques, and win extravagant prizes. All of this served to build not only women's self-confidence, but also their loyalty to Tupperware.

Tupperware's meteoric success and the resultant attention the business world lavished on Brownie Wise soon wore thin on Earl Tupper. Despite the fact that he had originally been on board with his company's extensive promotion by Wise, she received so much publicity that Tupper became jealous. Wise was fired without reason. She went on to start four more home party companies, but none of them were as successful. She died in Kissimmee, Florida, in 1992.

Deborah L. Daughetee

See also Vol. 2, Sec. 2: Washing Machine, Electric

Further Reading

- Clarke, Alison. 2001. *Tupperware: The Promise of Plastic in 1950s America*. Washington, D.C.: Smithsonian Books.
- Wise, Brownie. 1957. *Best Wishes, Brownie Wise*. Orlando, FL: Podium.

Xerox Corporation

The Xerox Corporation began as the Haloid Company in 1906 in Rochester, New York. It “offer[ed] products in office equipment and furniture” and aimed to aid businesses with technology and services with more intelligent document management. It offers printers, color and black-and-white copiers, and digital presses, plus the supplies, software, and support that go with them.

The Haloid Company did not become Xerox until 1961. It first became Haloid Xerox in 1958, a nod to its banking on the dry printing process. “Xerox” is a word coined by the company from two Greek words meaning “dry writing.” The company was successful, specializing in photographic paper and lithography. It had even been able to make a profit during the Great Depression and thrived during World War II. However, its market share decreased as the war wound down, and its president, Joseph C. Wilson (1909–1971) began to search for a new product.

Wilson was the grandson of one of Haloid’s founders and the son of Joseph R. Wilson, the president who took Haloid public in 1935. He became president of Haloid in 1945. He had John Dessauer search for a viable new product. This led to an interest in Chester Carlson’s “xerography” process. It made photographic copies on plain paper rather than coated paper. Wilson made a deal with Carlson, eventually getting most of his patents and the rights to his machine. It was a bet that paid off and made many Rochesterians “Xerox millionaires.”

Wilson and Dessauer went to Battelle Laboratories in Columbus, Ohio. Battelle was impressed with the men’s photographic copy process, though officials at the company worried that it might not be commercially viable. Wilson contacted Sol Linowitz, a Rochester attorney who negotiated with Battelle. The price

to Haloid was \$25,000 per year and 8 percent of the revenues from “electrophotography.”

The first public demonstration of xerography took place in 1948 on October 22. It was the 10th anniversary of Chester Carlson’s invention of electrophotography. Wilson unveiled a red box that made one copy in one minute. It was a promise of things to come; Wilson’s father predicted that the Xerox machine would be commercially viable by 1950—but it was not. Wilson began to secure new patents and to gain sole rights to Carlson’s work. Because the original patent would expire in 1957, these steps helped insure that Haloid would be in a good position when it did.

In 1955, Xerox produced Copyflo, the first copier that used xerography. Copies were made from microfilm. It was a start and gave hope to those who believed in the company. The company put \$75 million into xerography development between 1947 and 1960. That was twice its earnings. In today’s dollars, it was about \$530 million. Wilson bet the company on the success of Xerography—he even mortgaged his home.

Wilson won the bet, and the company entered a long period of profitability. In 1958, Haloid and Rank announced a merger to serve both the United States and Europe. In September of the next year, the 914 was unveiled. It was the first true Xerox machine providing rapid copies on normal paper. Xerox continued to be a technological innovator, coming out with one innovation after another.

The center of these innovations was the Xerox Palo Alto Research Center, generally called the PARC. It opened a year after Xerox moved its corporate headquarters to Stamford, Connecticut, in 1969. The PARC is near Stanford University, and Xerox hoped to draw on the school’s scientific resources for development aid. In 1973, Xerox developed the very first personal computer. The company named it the Alto. A number of innovations emerged from the PARC in its first decade of operation, including the first mouse, a bitmapped display, and a graphical interface. The result was the 8010 Star computer. Xerox’s Star was developed 8 years before IBM’s and more than 10 years before Steven Wozniak and Steve Jobs developed their first Apple Computer. Indeed, Wozniak and Jobs co-opted many of the Star’s features, including the use of folder icons and graphic user interfaces, the two button mouse, and e-mail.

While Xerox was at the forefront of personal computer innovation in the 1970s, the company rejected the Alto design and virtually ignored the work done at PARC. By the time Xerox realized its mistake in the 1980s, the Apple II, which used a mouse-central interface, had changed the computer market. Xerox never seriously competed in the home computer market though it had been a leader in business technologies for decades. The only major innovation from the PARC on which Xerox made great commercial profit was the laser printer.

Frank Salamone

See also IBM 360 Computer; Universal Automatic Computer (UNIVAC); *Vol. 3, Sec. 2*: Apple; Micro-soft; *Vol. 3, Sec. 3*: Netscape

Further Reading

Jacobson, Gary, and John Hillkirk. 1986. *Xerox: American Samurai*. New York: Macmillan.
Smith, Douglas K., and Robert C. Alexander. 1999. *Fumbling the Future: How Xerox Invented, Then Ignored, the First Personal Computer*. New York: Universe.

Primary Document: Patent for Xerography (1956)

Reproduced here are excerpts from the patent for xerography, which is a photocopying technique. There are many ways to produce photocopies, including more recent developments that allow for advanced digital photocopying. However, the discovery of xerography is what led to the very first commercial photocopier as we know it today by Xerox, making this technique fundamentally more important than others that have been developed since. This document, filed on May 2, 1956, contains a detailed technical description of the process as it was originally invented by Schaffert Roland for the Xerox corporation.

COLOR XEROGRAPHY Roland M. Schaffert, Columbus, Ohio, assignor, by mesne assignments, to Haloid Xerox Inc., Rochester, N.Y., a corporation of New York Filed May 2, 1956, Ser. No. 582,107
2 Claims. (Cl. 96-1) This invention relates in general to xerography and in particular to the xerographic reproduction of color images.

In the art of xerography it is usual to record and reproduce by electrical means a black and white copy of an original scene, document or the like. Such xerographic reproduction has been brought into commercial use for the making of line copy images and, to a certain extent, for continuous tone reproduction. At the present time, however, there is no system commercially available for producing colored xerographic prints. It is, therefore, an object of the present invention to provide means, method and

apparatus for the production of full colored xerographic prints.

It is a further object of the invention to provide means, methods and apparatus for two or more color xerographic reproduction and for the addition of other colors thereto.

It is an additional object of the invention to provide a new method for reproduction of xerographic images corresponding to two primary colors of light.

It is a still further object of the invention to provide new color xerographic apparatus comprising a light sensitive xerographic member characterized by having two separate sensitive xerographic layers each selectively sensitive to exposure by means of a different primary color.

It is a still further object of the invention to provide new means, methods and apparatus for color xerography whereby a xerographic print or reproduction in two colors can be produced with a single exposure to light of mixed primary colors.

In accordance with the present invention, a plurality of photoconductive layers of selected conductive sensitivity to light of different primary colors are simultaneously exposed to a projected light image of mixed primary colors. For example, a plurality of photoconductive layers may be superposed, one on top of the other in laminated configuration, and a light image of mixed primary colors may be projected onto the array of photoconductors from one side thereof so as to pass selectively through the first of the photoconductors in reaching the last of the

photoconductors. An electric field is applied through the photoconductive layers while they are exposed in this manner so as to produce a plurality of developable xerographic latent images which may be developed and superposed to form a two-color or full color xerographic reproduction.

AND:

What is claimed is:

1. The process of color xerography comprising projecting a light image consisting of a pattern of light and shadow of at least a first and a second primary color onto and through a first photoconductive insulating layer adherent on a substantially transparent conductive member and onto a second photoconductive insulating layer adherent on the opposite side of said member while maintaining an electric field through said layers to form an electrostatic latent image thereon, said first photoconductive layer being conductively sensitive to light of at least one first primary color and both substantially transparent to and substantially insensitive to light of at least one second primary color, said second photoconductive insulating layer being conductively sensitive to light of at least said second primary color, one of said photoconductive layers consisting essentially of a dispersion in a transparent insulating binder of a material selected from the group consisting of zinc oxide, cadmium sulfide, mixed zinc sulfide cadmium sulfide, zinc sulfide, zinc selenide and titanium dioxide, and the other of said photoconductive layers consisting essentially of a material selected from the group consisting of vitreous selenium, a dispersion of mixed cadmium selenide-zinc selenium in a transparent insulating binder, a dispersion of mixed lead oxide, zinc oxide in a transparent insulating binder, and a dispersion of mixed mercuric sulfide-zinc oxide in a transparent insulating binder, developing said

latent images with colored finely divided particles of colors complementary to said first and second primary colors respectively, and super-posing the developed color image for the first primary color with the developed image for the second primary color on a common support layer.

2. The process of color xerography comprising projecting a light image consisting of a pattern of light and shadow of at least a first and a second primary color onto and through a first photoconductive insulating layer adherent on a substantially transparent conductive member and onto a second photoconductive insulating layer adherent on the opposite side of said member while maintaining an electric field through said layers to form an electrostatic latent image thereon, said first photoconductive layer being conductively sensitive to light of at least one first primary color and both substantially transparent to and substantially insensitive to light of at least one second primary color, said second photoconductive insulating layer being conductively sensitive to light of at least said second primary color, said transparent conductive member being substantially transparent to the primary color of photosensitivity of said second photoconductive insulating layer and substantially opaque to the primary color of photosensitivity of said first photoconductive insulating layer, one of said photoconductive insulating layers comprising vitreous selenium and the other of said photoconductive insulating layers comprising zinc oxide in a transparent insulating binder, developing said latent images with colored finely divided particles of colors complementary to said first and second primary colors respectively, and superposing the developed color image for the first primary color with the developed image for the second primary color on a common support layer.

Source: United States Patent Office. Patent US2962375A. New York, Filed May 2, 1956, Serial No. 582,107.

Yalow, Rosalyn Sussman (1921–2011)

Nobel Prize–winning scientist Rosalyn Sussman Yalow developed the radioimmunoassay, a medical research tool that detects hormones and other proteins

by using radioactive markers. The process allows scientists to study the human endocrine system and treat diabetes, cancer, and thyroid disease.

Yalow was born on July 19, 1921, in New York City. Her parents were first-generation immigrants



Rosalyn Yalow, 1977 Nobel Prize winner for medicine, was an important advocate for the inclusion of women in science. (Bettmann/Getty Images)

from Eastern Europe. From a young age, Yalow was a prodigy in math and chemistry. In high school, her chemistry teacher encouraged her to enter the women's Hunter College, now City University of New York, as a chemistry major.

In 1939, Yalow attended a seminar presented by the famous nuclear physicist Enrico Fermi. Yalow found his discussion of the newly discovered nuclear fission process fascinating. Marie Curie further inspired Yalow, who switched her major to physics so she could study radiation and fission. She next applied to many graduate schools but was refused because she was a Jewish woman. Finally, she made a deal with Columbia University. She was able to take graduate-level classes if she agreed to take the stenography class and

work as a secretary for one of the physics professors. By January 1941, she was ready to quit. Fortunately, in February, the University of Illinois accepted her application, and she started there that fall.

On Yalow's first day at the University of Illinois, she met a man, Aaron Yalow, who would eventually become her husband. Aaron was a nuclear physics graduate student who also had an interest in medicine. Rosalyn Yalow was the only female student among the 400 male engineering students and the first one since 1917 to be accepted into the university. She finished her PhD in 1945 and moved back to New York to teach physics at Hunter College.

Aaron moved to New York a few months later and started to work at Montefiore Hospital in the Bronx. It

was through his work connections that Rosalyn Yalow was invited to start the first radioisotope service at the nearby Veterans Administration (VA) Hospital. Though this service was started in a room the size of a janitorial closet, it produced many groundbreaking publications on the medical application of physics and was replicated in many hospitals across the country. Yalow initially started as a part-time consultant and joined full time in 1950.

With Dr. Solomon A. Berson, Yalow published hundreds of scientific papers on radioimmunoassay. Berson died after they worked together for 22 years. The Nobel Prize committee could not recognize his contribution because it did not make posthumous awards. Yalow memorialized the laboratory they shared by renaming it the Solomon A. Berson Research Laboratory.

The radioimmunoassay, while winning the Nobel Prize for its incredible contribution to medical science, works on a relatively simple concept. It starts with a radioactive particle of iodine being attached to an antigen, which is a small and unique block of molecules found on most things in the bloodstream. Antigens are “marked” by the body with an antibody, a larger and Y-shaped protein that is specially made for each type of antigen. If the antigen is harmful to the body, it will signal the immune system to attack and destroy anything marked by the antibody.

Yalow and Berson’s discovery was to take a known amount of radioactive antigen and an unknown amount of a patient’s antigen and mix them in a solution of a known amount of an antibody. The antibody did not distinguish between the radioactive and nonradioactive antigens and would bind both of them proportionally. In other words, if there are two radioactive antigens for every nonradioactive antigen, the bounded antibodies will reflect this ratio.

Yalow was driven to find a treatment for her husband, who was diabetic. One of the first hormones they investigated was insulin. Yalow and Berson could have made a fortune from the commercial applications, but they did not apply for a patent. Instead, they preferred that other researchers use their discovery to make progress in treating diseases—and it is for this reason that Yalow was awarded the Nobel Prize in Medicine. She retired from the VA in 1991 and passed away on May 30, 2011.

Elliott Popel

See also McClintock, Barbara; Taussig, Helen; *Vol. 3, Sec. 2*: Perlman, Radia

Further Reading

McGrayne, Sharon Bertsch. 2001. *Nobel Prize Women in Science: Their Lives, Struggles, and Momentous Discoveries*. Washington, D.C.: Joseph Henry.

2. The Post–Cold War Era (1980–1999)

OVERVIEW

The post–Cold War years saw the flowering of technology and innovation after a number of technological advances were released from the cocoon of military secrecy. The decades of the 1980s and 1990s signaled the death of several existing industries and generated unimaginable wealth in others. It was the era in which most people would come to know the names of Bill Gates and Steve Jobs, but few had ever heard of Tim Berners-Lee, who made it all possible.

Along with astounding advances in technology, science, consumer electronics, and home entertainment, the 1980s and 1990s also saw the proliferation of two major myths: the “paperless office” and the “millennium meltdown.” The era also ushered in the plague of computerized identity theft and introduced a nasty new four-letter word into the language: “hack.” In short, the post–Cold War years became a golden age for computers, consumers, and con artists.

Lifting the Veil

Not only did technology itself blossom between 1980 and 1999, but the post–Cold War years saw the *rate* of technological innovation accelerate exponentially. To many, the rapid advance of innovation was miraculous. For some, it was immensely profitable.

However, others were confounded by the dizzying rate of obsolescence. In the post–Cold War age of technological advances, it seemed that as soon as a consumer bought a new piece of electronics, it was outdated almost immediately, becoming an embarrassment to the purchaser who had so recently beamed with pride over that same acquisition.

The post–Cold War years also began hurtling toward the new millennium with a proliferation of choices. This was said by experts to instigate a perpetual state of buyer’s remorse about whether it was the right choice to buy this cereal or that cell phone plan, that laundry detergent or this laptop.

While the technological advances of the post–Cold War years in the 1980s may appear quaintly dated today, they actually signaled the biggest socioeconomic upheaval since the Industrial Revolution. The post–Cold War information age was a product of the Digital Revolution, or the advancement of technology from analog and mechanical devices to digital, electronic circuits. Digital information is recorded as a series of the numbers 1 and 0, to show that a signal is either positive (1) or nonpositive (0).

Those innovations took place only after the veil of military secrecy during the Cold War was lifted. When that happened, amazing things were revealed.

United States vs. USSR

The Cold War was a time of ideological conflict, military tension, and global political competition that followed World War II, lasting from the late 1940s until the 1990s. The struggle was essentially between the United States and the Western world against the Union of Soviet Socialist Republics (USSR) and the communist Eastern Bloc.

In a global variation of the adage that “the enemy of my enemy is my friend,” the United States and Soviet Union were allies against Germany during World War II, but growing tensions revealed that they had vastly different visions for the reorganization of postwar Europe. As the Soviet Union held eastern

European countries behind an “Iron Curtain,” the goal of the United States was to contain the spread of communism around the world.

With the ever-present threat of global thermonuclear war hanging over their heads, the United States and USSR did not clash directly. Instead, they built alliances, engaged in espionage and counterespionage, deployed forces strategically, squared off economically, and fought a propaganda war. They vied for the hearts and minds of the “Third World,” competing not only in technological areas such as the “Space Race” but also in fields like athletics during such events as the Olympic Games.

Ripple Effect

A small incident in 1980 led to a huge ripple effect in which the Cold War steadily decelerated. Behind the Iron Curtain, Polish shipyard workers went on strike, forming the Solidarity Union led by the charismatic Lech Wałęsa. Simmering resentments came to the surface in other communist-controlled countries.

In 1985, Mikhail Gorbachev became the leader of the Soviet Union, declaring a policy of glasnost (“openness”) and perestroika (“restructuring”). Through the 1980s and 1990s, one event followed another as Chinese protestors demonstrated in Tiananmen Square for reforms in China, East Germany allowed unrestricted migration to West Germany, former Soviet-controlled countries like Poland and Hungary declared non-Communist governments, and the Berlin Wall was demolished in 1989. With the abolishment of the Soviet Union in 1991, the Cold War was, for all intents and purposes, grinding to a halt.

ARPANET to Internet

During the Cold War, there had been a dramatic expansion of state-funded scientific and technological research on both sides. The governments of both the United States and USSR encouraged and supported technological projects that were kept under wraps, subject to restrictions said to be due to national security.

The obvious research areas were in military weaponry and the Space Race, but Cold War-era research

also affected areas such as agriculture, biologicals, chemistry, and medicine. However, the greatest impact would come in the field of computer science.

The end of the Cold War allowed many technologies that were formerly military secrets to become declassified and open to the public. The area of greatest magnitude—many might say revolutionary—was a system created by the Pentagon to keep in touch following a nuclear war. It was called ARPANET, short for “Advanced Research Projects Agency Network.”

During the Cold War years, ARPANET had been funded by the Advanced Research Projects Agency of the U.S. Department of Defense. When restrictions were lifted, the public would come to know it as the Internet. By that name, it took over the world.

America (and Everyone Else) Online

A few individuals started utilizing the Internet as soon as it opened to the public in the 1980s, with a much larger user group joining in the 1990s. Even then, people who used the Internet by going “online” in 1995 constituted only about 20 million users, or less than one-half percent of the world’s population at the time. They were mostly from the United States or a few other Western countries.

That figure grew exponentially in successive years to the point where the number of users was virtually impossible to track. Devices requiring Internet access would become common all over the world by the twenty-first century.

Central to this revolution was the mass production of digital logic circuits and derived technologies that enabled widespread use of computers, digital cellular phones, and the Internet.

A clearer picture of the post-Cold War era that began in the 1980s can be seen in a chronological look at the technological advancements that burst forth in computers. In 1982, the IBM personal computer (PC) allowed individuals to have data-processing devices to use at home or in a small office setting.

In 1983, the Global Positioning System, or GPS, was opened for use by civilian aircraft. It began a trend that led to Geographic Information Systems (GIS) and mapping tools used at first by entities like state and local governments, ultimately finding a place on auto

dashboards with a pleasant electronic voice telling drivers where to turn.

By 1984, several industries were in the process of being flattened by the advent of the compact disc read-only memory (CD-ROM), an optical-based disc that contains data but is usually neither writable nor erasable by the consumer. It signaled the demise of floppy discs for computer data storage as well as music on vinyl records and cassette audiotapes. It would soon overtake videotapes in the form of digital video discs (DVDs).

Meanwhile, that same year, flash memory was finding its place in small electronic devices. Digital cameras, cellular telephones, and the rise of the laptop computer would all come to rely on flash.

Start the Revolution

Although many people today might find it hard to believe, the World Wide Web was not always something that was simply “there,” like air. It was, in fact, something that had to be invented. That was accomplished in 1989 by Tim Berners-Lee, an Englishman working in Switzerland at CERN (Conseil Européen pour la Recherche Nucléaire, or European Council for Nuclear Research).

CERN had been established in 1954, during the frozen depths of the Cold War, but some of its greatest triumphs took place in the post–Cold War years of the 1980s and 1990s. These include the discovery of W and Z bosons (1983), work with light neutrino families at the Large Electron-Positron Collider (LEP) in 1989, and the creation of antihydrogen atoms (1995).

In 1988, while working on networking computers at CERN, Tim Berners-Lee began discussing a possible linked information system with his colleagues. By the end of 1990, his idea was implemented as the World Wide Web with its Hypertext Transfer Protocol (HTTP) and Hypertext Markup Language (HTML). Generally known simply as the “Web,” it revolutionized the world for business, communications, and individuals around the globe.

Through the 1990s, getting online entailed a complicated configuration and the aid of telephone equipment. With the breakup of the Bell System in 1984,

new telephone providers proliferated. Microwave links began to spring up along major corridors to provide service. Fax machines replaced telex in the 1980s. Answering machines evolved into voice mail.

Soon, even the advances in telephone technology veered in another direction as dial-up online service gave way to more advanced Internet connectivity in the 2000s.

Rise of the Luggables

For many people, the personal computer became a window on the world, bringing a wealth of information that was previously unimaginable to their fingertips, right in the comfort of their home or workplace. But others sought to keep their computers with them as they moved about the larger world beyond their house or office. Enter the laptop.

First called “luggables,” the folding units included a display and keyboard and were meant to travel, though they had limited battery life and had to be plugged in to both a power source and Internet connection wherever they were to be used. Due to their size and weight, today these early laptops are almost unrecognizable as portable computers, but they laid the groundwork for the devices that would follow.

The first mass-produced portable computer with a microprocessor was the Osborne 1, released in 1981. With a screen width of only five inches, it was heavy, bulky, and about the size of a sewing machine. But for the first time, a person’s computer and data could travel, even on commercial aircraft.

Throughout the 1980s and 1990s, other portable computers hit the market. The Compaq Portable was introduced in 1982, followed by the Tandy Model 100 in 1983. Commodore’s SX-64 was released in 1984. The Gavilan SC was first sold in 1984 and is noteworthy for being the first documented computer to be marketed as a “laptop.”

Other early laptops in the 1980s included the IBM PC Convertible and Hewlett-Packard Vectra Portable CS. Apple Computer introduced the Macintosh Portable in 1989, although 1984’s earlier transportable, the Apple IIc, had an optional liquid crystal display (LCD) screen. LCDs were much thinner than displays using cathode ray tube (CRT) technology.

It was the Apple PowerBook series of 1991 that is said to have pioneered the changes that became standard on laptops, such as a pointing device or trackball. The following year, IBM released its ThinkPad 700C featuring a similar design with a TrackPoint. Other laptop computers followed during the 1980s and 1990s, becoming lighter, thinner, and smaller with each incarnation until they too were considered prehistoric in the 21st-century age of the tablet and smartphone.

Nexus, Explorer, and Chrome

The 1990s brought a cascade of technological innovation to make the Internet accessible to average people. The Web browser, a way of navigating and retrieving information from the World Wide Web, was invented by the creator of the World Wide Web itself, Tim Berners-Lee. Browser software became more and more user-friendly through the 1990s, with versions evolving through the turn of the century with names including Nexus, Erwise, Mosaic, Netscape Navigator, Internet Explorer, Mozilla Firefox, Safari, and Chrome.

In 1993, electronic mail, or e-mail, took off with the speed of light. Though versions of e-mail could be traced back to the 1960s in the Cold War era, by 1997, the volume of business e-mail surpassed that of traditional postal mail.

The Web would light up in a dazzling array of images by 1994 made possible by the Joint Photographic Experts Group (JPEG). It now carried graphics, pictures, and photos. The next year, Microsoft introduced Windows 95, an operating system geared to “user-friendly” consumer operation.

The Internet search engine Google made its appearance in 1998. It became the most popular way to find needed information on the Internet, though it was not the first. Some earlier search products included WebCrawler and Lycos (1994), AltaVista, Excite, and Yahoo! (1995), and HotBot and Ask Jeeves (1996). It was the word “Google,” however, that would enter the language as shorthand, as in “to Google,” meaning to search for information online. The word “google” itself is a variation on the term “googol,” referring to the number 1 followed by 100 zeros, or a virtually infinite number.

The end of the post-Cold War era also brought about the technology to free Internet users from being tied to wiring. The year 1999 saw the emergence of Wi-Fi, the wireless networking technology that uses radio waves to provide high-speed Internet. Wi-Fi would become indispensable for those who wanted to shop online from a local coffee house upon the rise of e-commerce Web sites, which began being built in 1994. Companies offering e-commerce only, such as Amazon.com and eBay, quickly mushroomed.

Send in the Clones

Post-Cold War technology and innovation was not limited to computers. It found its way into genetics, outer space, and America’s dinner tables. In 1986, “Baby M,” the first child produced from a gestational surrogacy, was born, marking the first time in history that a child was born to someone other than the biological mother. Ten years later, in 1996, Dolly the sheep was cloned.

Looking skyward, the Hubble Space Telescope was launched in 1990. It revolutionized astronomy by allowing a deep view into space and time. That same year, construction began on the International Space Station. NASA’s *Pathfinder* landed on Mars in 1997, with a robot rover providing a close-up view of the Red Planet.

Post-Cold War technology landed squarely in American kitchens during 1994 with the introduction of the FlavrSavr tomato, the first genetically modified food sold in the United States.

“Must-Have” Technology

Consumer electronics really took off during the post-Cold War years. Many burned brightly as the hottest, most beloved “must-have” items on the market until they flamed out, usually being replaced by more advanced technology.

In 1980, the Sony Walkman was introduced to the United States, spurring a revolution in personal audio habits. After installing small batteries, listeners could play their favorite radio station or cassette tapes through lightweight earphones, adding an enjoyable

dimension to commuting, walking, working out, etc. In 1984, Sony introduced the portable Discman to play compact discs (CDs).

The beloved videocassette recorder (VCR) ruled the 1980s. People could record their favorite TV shows or watch movies whenever they wished. At the beginning of the 1980s, only a few people owned VCRs, with many waiting out the “format war” as Sony’s Betamax went head to head with VHS (Video Home System) from the JVC Corporation. Consumers fully understood that videotapes from one format would not be compatible with the other if the system they bought did not emerge victorious.

Due to costs, length of recording time, and other factors, VHS won that particular format war. However, Sony achieved payback with the success of its Blu-ray disc in the 2000s, by which time all VCRs were giving way to DVD technology.

Gordon Gekko’s Brick

The cellular telephone, or cell phone, was marketed to the public by Motorola in 1983. There were early versions of car phones and the “bag phone,” a plug-in mobile telephone device that came in a pouch. But it was the success of the 1987 movie *Wall Street* that helped cell phones turn the corner. Actor Michael Douglas as Gordon (“Greed, for lack of a better word, is good”) Gekko made a wireless call from the beach in chic Southampton, New York, catapulting the mobile phone into the spotlight as an 1980s icon. Gekko’s phone was the size of a brick, but it placed the cell phone firmly in the popular mind as synonymous with wealth, power, stylishness, and upward mobility, all deeply attractive to many in the 1980s.

Those who weren’t clawing their way to the top found other ways to pass the time in the post–Cold War years. In 1977, the video game console began filling the screens of American TVs in the form of *Donkey Kong* and *Pac-Man*. However, it was in 1985 that the Nintendo Entertainment System (NES) launched the Nintendo empire in America with such games as *Super Mario Bros.* Nintendo would be the forerunner of the Sony PlayStation avalanche of the 1990s and beyond.

It’s a Small World

The 1980s also saw a number of small digital devices become affordable, accessible, and desirable. The advancing technology of microprocessors combined steadily increasing performance with smaller size, allowing computer technology to find its way into everyday objects from cameras to calendars.

Digital cameras were commercially available by 1989 and generally replaced traditional photographic film by 2010. Personal digital assistants (PDAs) helped people keep track of their lives starting with the release of the Apple Newton in 1993. Later incarnations gradually merged their calendar features with cell phones.

The current incarnation of the automated teller machine (ATM) became commonplace in the United States during the 1980s, dispensing cash to eager Americans.

The field of home entertainment hit the big time in the post–Cold War years. Like full-color, flat-panel computer monitors, flat-screen TVs came to dominate the industry, sealing the demise of bulky cathode ray tube (CRT) screens and traditional television sets.

People also gained exciting new choices of programming to watch on their flat-screen TVs. In the 1980s, video stores allowed people to rent their favorite movies on videotape to watch at home. Those physical, “brick-and-mortar” shops would ultimately give way to video on demand via cable TV systems and video-by-mail services such as Netflix, which was launched in 1997, offering DVDs mailed directly to people’s homes. After the turn of the millennium, even those went the way of the dinosaur with the advent of computerized streaming, on-demand, and other services offering innumerable choices.

Smart Cars

The computers that came into flower during the post–Cold War years found their way into all manner of devices, including those that powered American transportation. From airlines to automobiles, computers took charge. Shade-tree mechanics began to find that their monkey wrenches were no match for tiny computer chips.

Automotive technology relieved the driver of a number of manual tasks like opening car windows, which were controlled by small motorized electronic mechanisms. Traditional car keys gave way to key fobs with embedded electronic chips. CD players replaced dashboard cassette decks. GPS navigation spared the driver from map reading.

TMI

During the 1980s and 1990s, the steady development of transmission technologies including computer networking, digital broadcasting, and the Internet brought previously unimaginable choices to Americans. To some people, the post–Cold War proliferation of technology and innovation hurt as much as it helped. Some cited negative effects of the digital revolution such as information overload, Internet predators, media saturation, social isolation, and a constant state of “buyer’s remorse” from having too many choices and too-rapid obsolescence.

The field of journalism was especially vulnerable as bloggers, tweeters, and other self-proclaimed “citizen journalists” with keyboards muddled the lines between personal opinion and documented reporting. Conspiracy theories multiplied, often with online sources simply reprinting verbiage from other Web sites, dubious or otherwise. With the advent of post–Cold War technology, both individuals and organizations suddenly had the ability to disseminate their views inexpensively on any topic to a global audience.

Thieves Rush In

One group especially rejoiced in the rise of post–Cold War technology for the public. They were the identity thieves who found they could “hack” their way into the Internet accounts of individuals and organizations. Criminals could steal personal and corporate information that allowed them to commit acts from applying for fraudulent loans using someone else’s credit cards to simply cleaning out people’s bank accounts. Accessing the computerized personal information of thousands of Americans, thieves could in turn sell the data on the black market.

The issue of privacy in general became a concern during the digital revolution of the 1980s and 1990s.

With huge amounts of all kinds of information being stored via computers and vulnerable to hacking, the activities and interests of private citizens could be tracked by computer monitoring and shadowy surveillance. Soon, people who assumed their e-mail messages were private often had a rude awakening.

Paperless Pipe Dream

Certainly, many people found the advantages of the post–Cold War digital revolution to outweigh the drawbacks. Experts predicted that American businesses would transform into “paperless offices,” work environments where the use of paper was greatly reduced or eliminated entirely.

By converting paperwork into digital form, proponents claimed that going paperless could save space and money and allow convenient sharing of documents, enhance productivity, keep personal information more secure, and help the environment.

Even at home, they argued, going paperless would mean the demise of such things as cookbooks and “hard-copy” recipes after homemakers converted their bulky, disorganized collections to computerized files.

However, as Greg Milliken wrote on WIRED.com in 2014, “When many organizations first began to transition from paper to electronic documents in the 1980’s, there was an initial reduction in the amount of physical paper used, but the truth is that we use more paper today than during the days of the Pet Rock.” Milliken cites statistics indicating that a billion photocopies are made each day and that the amount of paper generated by the average company grows by 25 percent each year.

The “paperless office” simply did not happen as predicted. Some of the reasons include the costs and productivity losses when converting to a paperless office. There was also the demand that all end users have the same hardware and software for reading documents as well as the same level of technological skills. Some skeptics also question the longevity of digital documents and system stability.

In addition, historians note that a large part of human history is known through written documents. Digital records can often be easily created but also easily modified or deleted altogether. And, changes in

storage formats can make data recovery difficult or impossible. Those with large amounts of information on floppy disks found out the hard way when floppies went the way of the eight-track tape.

Why 2K?

Another by-product of the post–Cold War years was the feared “millennium meltdown” or “Year 2000” problem, usually abbreviated simply as “Y2K.”

People—and especially the news media—took note of the issue in the late 1990s, as the turn of the century in 1999 would be followed by the new millennium. In the early days of the post–Cold War computer wave, storage was at a premium. In an effort by programmers to reduce usage, the date stored in many internal programs was formatted as six digits in the form of MMDDYY. “MM” was two digits for the month, “DD” was two digits for the day, and “YY” was two digits for the year. The prefix “19” for the year was felt to be understood; in other words, “July 1, 1985” was stored as “070185.”

It was speculated that some programs would not be able to distinguish between the year 2000 and the year 1900, with other programs trying to represent the year 2000 as 19100. There was fear of a complete system collapse, with results ranging from the inconvenient to the catastrophic as public utilities and critical infrastructure might fail. Some people cited nuclear power plants as a particular area of concern.

Businesses and governmental agencies sought to find all the areas that might be affected. In many cases, upgrading computer systems was assumed to be a solution. Still, it was hard to think of everything. Special committees were tasked with contingency planning if communications and crucial utilities were to fail. The Federal Emergency Management Agency (FEMA) looked to possible effects across the nation. While many felt the scare was overblown, most entities adopted a policy of “better safe than sorry.” Nothing could be certain until the calendar flipped to January 1, 2000.

Some organizations and agencies have since claimed that they sent out hundreds of press releases with research suggesting that the Y2K issue was not likely to be a problem. However, they were largely ignored by the news media in the face of meatier angles.

On January 18, 1999, a year before the supposed Y2K event, a leading national news magazine ran an eye-catching cover. A figure resembling a biblical prophet wore a sign saying, “The END of the World!?! Y2K insanity! Apocalypse Now! Will computers melt down? Will society? A guide to MILENNIUM MADNESS” (sic).

The inside story concluded that the necessary programs would be corrected in time, and the end of the world was unlikely. However, people seeing such a cover on newsstands without reading the article might be forgiven for assuming the worst. A Y2K-themed thriller feature film and made-for-TV movie were released. Wilderness survival boot camps became popular. Food and ammunition were stockpiled. Sources reported a spike in sales of SPAM canned meat.

When the clocks rolled over to January 1, 2000, there were no widely reported computer failures. Many looked back on the Y2K scare as a quaint piece of popular culture like radio’s *War of the Worlds* Martian mania in 1938. But many of those same people would not willingly have been flying in an airplane on December 31, 1999, at 11:59 p.m.

Orwellian World

With the rapid advances in computer technology during the post–Cold War era of the 1980s and 1990s, some people questioned the safety of storing vast amounts of personal data. Many forms of private information were being stored electronically at levels that were previously unseen. Some people feared not only identity theft but also the ability by the government and other entities to track individual activities and interests, such as which books they checked out of the library or which Web sites they visited. Advocates of privacy rights feared that by monitoring personal information, powerful centralized forces could control the population.

Some people had a term for the computerized world of the post–Cold War era: “Orwellian.” They were those who saw the 1980s and 1990s as actually the future envisioned by writer George Orwell. And it happened right on schedule: in 1984.

The book *Nineteen Eighty-Four* by English author Orwell was published in 1949. It is often called a

“dystopian” novel, depicting an unpleasant, dehumanized world controlled by a totalitarian state. There is constant government surveillance in *Nineteen Eighty-Four* along with manipulation of the public, persecution of individualism, rewriting of history, secret surveillance, and unending war. The government is controlled by the privileged elite of the Inner Party, which invented a language called Newspeak in which independent thinking is condemned as “thoughtcrime.”

In *Nineteen Eighty-Four*, the ruling party seeks power entirely for its own sake—just to *have* power instead of using it to help the people. The party leader is called Big Brother, who may not actually exist but attracts followers based on an intense cult of personality.

In Orwell’s dystopian world of the year 1984, the job of some workers is to rewrite past newspaper articles so that the historical record always supports the ruling party. In being instructed to forge and falsify documents, workers are told that they are correcting “misquotations.” Documents that cannot be altered are simply destroyed so no record exists of the government’s dishonesty.

Nineteen Eighty-Four meets 1984

In the actual calendar year 1984, there were numerous articles by contemporary writers who sought to determine how much of *Nineteen Eighty-Four* had actually come true. With the advent of e-mail, chat rooms, instant messaging (IM), and a later incarnation of messaging, texting, Newspeak’s truncated version of English became commonplace in the real world—“amirite?” The government-promulgated Newspeak in *Nineteen Eighty-Four* was rather more sinister, with such terms as “crimethink,” or ideas that were apart from the official government party line.

The new abbreviated language in the reality of the digital age was more geared to speed and convenience, such as BTW (“by the way”), B4N (“bye for now”), GR8 (“great”), IMHO (“in my humble opinion”), IRL (“in real life”), j/k (“just kidding”), L8R (“later”), and LOL (which could be either “laughing out loud” or “lots of love”). Much on the Internet today could be categorized as “DBEYR” (“don’t believe everything you read”).

A larger issue for many people in the post–Cold War computer age was the threat of the surveillance state as seen in *Nineteen Eighty-Four*. The concept of Big Brother was already being seen as a concern in the 1980s and 1990s, even before legislation after the terrorist attacks of September 11, 2001, made it easier for the government to conduct surveillance.

In the book *Nineteen Eighty-Four*, “telescreens” are dual-purpose devices, both playing televised propaganda and recording users’ activities. The two-way devices that became popular in the reality of the post–Cold War era were cell phones, which can be used to track and record their users.

Another feature of the book *Nineteen Eighty-Four* was providing the people, especially the poor, with a steady stream of diversions to fill their minds. Women were kept occupied with the care of home and children. Orwell wrote of the sports, entertainment, pornography, and gambling that were made easily available to the masses. Quarrels were promoted among different groups. The idea was to occupy the masses with distractions so they would not question the machinations of the government.

With the rise of actual computer-age arenas like Internet gambling, online pornography, and fantasy sports Web sites, some people felt that the real world of the 1980s and 1990s was Orwell’s fictional *Nineteen Eighty-Four* come to life.

With all its pluses and minuses (or *1s* and *0s* in digital form), such was the complex legacy of technology and innovation in the post–Cold War era.

Nancy Hendricks

Further Reading

- Becraft, Michael B. 2014. *Bill Gates: A Biography*. Santa Barbara, CA: Greenwood.
- “The END of the World!?! Y2K Insanity!” 1999. *TIME*, January 18, cover.
- Isaacson, Walter. 2013. *Steve Jobs*. New York: Simon & Schuster.
- Isaacson, Walter. 2014. *The Innovators: How a Group of Hackers, Geniuses, and Geeks Created the Digital Revolution*. New York: Simon & Schuster.
- Leffler, Melvyn P. 1992. *A Preponderance of Power: National Security, the Truman Administration,*

- and the Cold War*. Palo Alto, CA: Stanford University Press.
- McPherson, Stephanie Sammartino. 2010. *Tim Berners-Lee: Inventor of the World Wide Web*. Minneapolis: Twenty-First Century Books.
- Milliken, Greg. 2014. “The Paperless Office: 30-year Pipe Dream?” WIRED.com. <https://www.wired.com/insights/2014/01/paperless-office-30-year-old-pipe-dream/>, accessed August 30, 2018.
- Oreskes, Naomi, and John Krige, eds. 2014. *Science and Technology in the Global Cold War*. Cambridge, MA: MIT Press.
- Orwell, George. 1961. *Nineteen Eighty-Four*. New York: Signet Classic.
- Rose, David. 2015. *Enchanted Objects: Innovation, Design, and the Future of Technology*. New York: Scribner.
- Sellen, Abigail, and Richard Harper. 2001. *The Myth of the Paperless Office*. Cambridge, MA: MIT Press.
- Tenner, Edward. 1997. *Why Things Bite Back: Technology and the Revenge of Unintended Consequences*. New York: Vintage.

AIDS Research

The history of the human immunodeficiency virus (HIV) and the illness it causes, acquired immune deficiency syndrome (AIDS), began in fear and death as the world faced a new, unknown pathogen. However, scientific advances, such as the discovery of the virus and how it is transmitted, the development of effective treatments, and new methods of prevention, have begun to limit the spread of the disease and enabled people with access to treatment to live longer and much healthier lives. When the U.S. Centers for Disease Control and Prevention (CDC) published information about early cases, it was the first official reporting about AIDS.

According to the Joint United Nations Programme on HIV/AIDS (UNAIDS), in 2015, there were 36.7 million people living with HIV; since the start of the epidemic, around 78 million have become infected.

It is widely believed that HIV originated in about 1920 in Kinshasa, in what is now the Democratic Republic of Congo, when HIV crossed species from

monkeys and apes to humans. The first verified case of HIV was found in a blood sample taken in 1959 from a man who lived in that region, which was retrospectively analyzed.

Up until the 1980s, it is not known how many people were infected with HIV or developed AIDS. The first cases were likely isolated ones among villagers who hunted and/or ate the meat of monkeys and apes. While sporadic cases of AIDS had been documented prior to 1970, available data suggests that the current epidemic started in the mid-to-late 1970s.

In 1981, five cases of a rare lung infection called *Pneumocystis carinii* pneumonia (PCP) were found in young gay men in Los Angeles. The CDC published information about these cases in its *Morbidity and Mortality Weekly Report* (MMWR).

Shortly thereafter, reports surfaced of young gay men in New York and California who had been diagnosed with a rare cancer called Kaposi’s sarcoma. This cancer forms from cells that line lymph or blood vessels and is caused by a virus. Both PCP and Kaposi’s sarcoma are usually found in people whose immune systems are suppressed. It was found that the men’s bodies were unable to fight these unusual infections. By the end of 1981, there were 270 reported cases of severe immune deficiency among gay men, and 121 of them had died.

Initially referred to as gay-related immune deficiency (GRID), in 1982, reports surfaced of cases in hemophiliacs and Haitians, indicating that the disease was spreading beyond American gay men. The same year, the CDC started to use the term “AIDS” to describe the illness.

In early 1983, the CDC suggested in another MMWR article that AIDS was caused by an infectious agent that was being transmitted sexually and/or through exposure to blood or blood products. U.S. health officials realized they had the makings of an epidemic on their hands, and Congress passed its first bill that included funds specifically for AIDS research and treatment.

A major outbreak of AIDS in Central Africa was then reported, signaling the beginning of the epidemic in other countries. The World Health Organization met in December 1983 to assess the global AIDS situation and start international surveillance.

The first scientific breakthrough in the cause of AIDS also came in 1983. Dr. Luc Montagnier and colleagues at the Pasteur Institute in France isolated a new retrovirus, which they initially called “lymphadenopathy associated virus” (LAV). Shortly thereafter, Dr. Robert Gallo of the National Cancer Institute also isolated it. Believing it to be related to a family of viruses called “human T-lymphotropic virus,” Gallo and his colleagues named it “HTLV-III” (it would be renamed HIV in May 1986).

This discovery was critical, for it enabled tests to be developed that could detect the presence of the virus in blood. It had been shown through the cases of HIV in hemophiliacs that the virus could be transmitted to others via blood transfusions, and there was great fear about contamination of the blood supply. At the time, in some U.S. cities, an estimated 1 in 90 transfusions was infected with HIV.

Researchers worked frantically on this problem. In March 1985, the U.S. Food and Drug Administration (USFDA) licensed the first commercial blood test for HIV, called the “enzyme-linked immunosorbent assay” (ELISA). It did not find the virus directly but was able to detect the antibodies made by an infected person’s body to fight it. This test enabled blood banks to start screening their supplies, and people at high risk for contracting the disease could be tested as well.

Unfortunately, the discovery of the virus also showed that it had properties that make it very difficult to develop a conventional vaccine against. This made it crucial to find effective medications to fight it. The U.S. government and health research agencies poured money into the project. In October 1985, Congress allocated nearly \$190 million for AIDS research, almost 16 times the amount allotted in 1983.

In March 1987, the FDA approved the first drug treatment for HIV: zidovudine (AZT). AZT works by preventing the virus from multiplying. It was approved in record time with only one trial on humans instead of the standard three. That trial was stopped after only 19 weeks, because the group of control patients in the study who were not receiving the drug were dying faster than the ones who were. At the same time, the FDA issued new regulations to fast-track experimental HIV medications, accelerating drug approval by two to three years.

The early and mid-1990s would see the development of HIV tests that doctors could use in their offices, would show results in as little as 20 minutes, and that could use saliva or urine instead of blood. These simpler, rapid tests would prove to be valuable tools in countries where expensive and time-consuming tests were difficult to perform.

In June 1995, the FDA approved saquinavir, another drug that prevents the virus from replicating, but in a different way than AZT. This and subsequent approval of other drugs ushered in a new treatment regimen for AIDS called “highly active antiretroviral therapy” (HAART), which uses a combination of several medications that inhibit the virus in different ways. HAART brought about an immediate decline in rates of AIDS-related deaths and hospitalizations. While none of the drugs are a cure, they can hold the virus in check for prolonged periods if taken regularly.

In 1996, the Joint United Nations Programme on AIDS (UNAIDS) was established to advocate for global action on the epidemic and coordinate the response to HIV/AIDS among United Nations countries. UNAIDS was instrumental in negotiating with five pharmaceutical companies to reduce antiretroviral drug prices for developing countries, another critical piece of fighting the worldwide epidemic.

As older HIV medicines began to lose their patents, generic drug manufacturers began producing much cheaper versions for developing countries, causing several major pharmaceutical manufacturers to agree to further reductions in drug prices. In November 2001, the World Trade Organization (WTO) announced the Doha Declaration, which allowed developing countries to manufacture drugs to combat public health crises like HIV even if they still had patents.

In the early and mid-2000s, studies confirmed that medications could also be used as a means of preventing HIV transmission to people who were HIV-negative but at high risk of contracting the disease through sexual activity. These medication regimens, known as “pre-exposure prophylaxis,” or PrEP, include both oral medications and novel methods of delivery, such as the dapivirine vaginal ring designed to be a low-cost and discreet method of prevention for women in developing countries.

The years 2012 and 2013 marked turning points in the fight against AIDS, as UNAIDS reported that for the first time, the majority of people eligible for HIV treatment (54 percent) were receiving it. Additionally, new HIV infections had dropped more than 50 percent in 25 low- and middle-income countries, and AIDS-related deaths had fallen 30 percent since their highest point in 2005.

In September 2014, UNAIDS called for a massive and ambitious scaling up of HIV prevention and treatment programs to prevent new infections and end the epidemic as a public health issue by 2030. By 2016, UNAIDS announced that 18.2 million people were on drug therapy, including almost a million children, double the number five years earlier.

However, UNAIDS reports also noted an emerging problem with HIV mutations, which are resistant to first-line drug therapies partly as a result of patients not taking their medication regularly. This points to the importance of ensuring that people stay on

treatment and to the need for a vaccine or cure for HIV. In November 2016, the National Institutes of Health announced a large-scale vaccine trial in South Africa, which, if successful, may signal the next important breakthrough in AIDS research.

Nancy Beach

See also *Vol. 3, Sec. 1: Polio Vaccine; Vaccines*

Further Reading

France, David. 2016. *How to Survive a Plague: The Inside Story of How Citizens and Science Tamed AIDS*. New York: Knopf.

Quammen, David. 2015. *The Chimp and the River: How AIDS Emerged from an African Forest*. New York: W. W. Norton.

University of California at San Francisco Library. AIDS History Project: <https://www.library.ucsf.edu/archives/aids/>, accessed August 31, 2018.

Primary Document: Introduction to the AIDS Archive by Former Surgeon General C. Everett Koop

In this Introduction to AIDS Archive, which resides on the Profiles in Science Web site of the U.S. National Library of Medicine, former surgeon general C. Everett Koop explains how and why he began educating the American public about the disease. Acquired immune deficiency syndrome, a disease involving a severe loss of the body's cellular immunity that lowers the resistance to infection, first appeared in the United States in 1981, a year before Koop took his position in President Ronald Reagan's administration.

AIDS entered the consciousness of the Public Health Service quietly, gradually, and without fanfare. I was at a staff meeting in June of 1981, as the Surgeon General designate, when the Centers for Disease Control published a report and discussed it at a staff meeting concerning five “previously healthy homosexuals,” who had been admitted to Los Angeles hospitals with pneumonia caused by a very rare organism—pneumocystis carinii.

By the time the report was published, two of the men had died. The other three died shortly thereafter. Five cases are certainly not many, but this lethal pneumonia was so rare that a handful of cases in a single year—especially in a single place—constituted an epidemic. Soon reports trickled in of cases in other cities.

Then a month later, the Public Health Service published a report that 26 young homosexual men had been recently diagnosed as having Kaposi's sarcoma, an “uncommonly reported” cancerous condition, usually found, if at all, among elderly men.

I was the only one at the staff meetings who had ever seen pneumocystis carinii pneumonia, and that was because I worked in a children's hospital where I did lung biopsies to make that diagnosis in children who were immuno suppressed because of cancer chemotherapy. I had also seen one case of Kaposi's sarcoma in my entire life, and that at the Allgemeine Krankenhaus in Vienna. From that small beginning, the AIDS epidemic of the late 80s mushroomed.

Epidemiologists from Centers for Disease Control opined that these otherwise healthy normal people were apparently acquiring some type of virus that attacked and destroyed their immune system. The virus itself was not killing these people, they were succumbing to other extremely virulent diseases—eventually called “opportunistic diseases,” because this infectious agent, whatever it was, prevented the body from fighting them off. Since the first cases affected only homosexuals, the Public Health Service called the disease, “GRID”—Gay Related Immune Deficiency. Shortly thereafter, as heterosexuals began to fall victim to it, GRID became the “Acquired Immuno Deficiency Syndrome,” or A.I.D.S., which was shortened to just AIDS. Although, I was in on AIDS from the start, I didn’t assume an important role in government in reference to AIDS until the end of Ronald Reagan’s first term in office. By August 1981, I and others, who were paying attention to the unusual news from the CDC, learned that there were 108 cases of AIDS reported with 43 dead. I knew then that we were in big trouble. My first real confrontation with other members of the Public Health Service came when I said, “If this is a homosexual disease, one of the things we will have to come to grips with, early on, if we are to control it, is the forced sodomy which takes place in prisons and would be a source of rapid spread of the disease.” No one at the staff meeting agreed with me, and it was years before anyone, especially the Centers for Disease Control were talking about AIDS among prisoners.

I realize that if ever there was a disease made for a Surgeon General, it was AIDS. The Surgeon General is mandated by Congress to inform the American people about the prevention of disease and the promotion of health. If ever there was a public in need of education and straight talk about AIDS, it was the American people.

But for an astonishing five and a half years, I was completely cut off from AIDS. The Assistant Secretary for Health, my immediate boss, told me that I would not be assigned to cover AIDS. The Department took its cue from him. Even though the Centers for Disease Control commissioned the first AIDS Task Force as early as June 1981, I as Surgeon General was not allowed to speak about AIDS publicly until I took it upon myself to do so.

Whenever a two-term President is awaiting his second inauguration, and lame-duck congressmen and senators are packing boxes to move on, presidential appointees begin to leave Washington like rats leave a sinking ship. One of the things I realized early on about political appointments was that many accepted them in order to become expert in some phase of government operation so that they would be able to convert that expertise into big bucks. Indeed, a lot of them spent the President’s first term standing on tiptoe looking into the distance for that six-figure job.

As people in the Public Health Service, who had appointments by President Reagan began to go home, there was no one left to police me, and in as much as I felt better able to communicate with the public than anyone who was left, and really not understanding why I had been so confined, I began to attend meetings, ferret out information, and it remained for President Reagan to give me an assignment that catapulted me into the position of chief spokesperson for the government in reference to AIDS. When I say chief spokesperson that meant to the public, to the Congress, to the health departments of foreign governments, and to the United Nations itself.

It happened his way:

The day after President Reagan gave his “State of the Union” message after inauguration in 1987, he, in an unusual move, came across town to the Humphrey Building and in the great hall spoke to a packed house, standing in the atrium, about his gratitude to them for the way they were handling the health problems of the nation of which AIDS was one. Toward the end of his speech he said, “I’m asking the Surgeon General to prepare a report on Acquired Immuno Deficiency Syndrome for the people of the United States.” It’s good that I was listening carefully, because that’s the only directive I had from anyone about that report. I proceeded with an appropriate degree of urgency, selected a few close associates to be my staff for preparation of this document and then set about informing various segments of the public about what I felt I had to say about AIDS in the report, and learning from them which points were supersensitive, and would require discussion to me before the various organizations would accept what I felt essential to say to the public.

This story would not be complete if I didn't mention the fact that the Reagan revolution brought into positions of power and influence Americans whose politics and personal beliefs predisposed them to antipathy toward the homosexual community. This influenced the AIDS crisis in two ways. First, it slowed the understanding of AIDS. In the early years of AIDS, (also the early years of the Reagan Administration), health officials were shocked and dismayed by the link between the spread of AIDS and the promiscuity and perversity of many homosexuals' behavior. Revelations about the promiscuity of some homosexuals with multiple partners and the fact that sodomy with multiple anonymous partners provided valuable information about a possible method of AIDS transmission: semen of one to blood of the other, led to a profound reluctance on the part of some health officials to discuss these sensitive (some said abhorrent) issues publicly. So, under directions from more than one White House source, they simply made vague references to "exchanging bodily fluids" thus, considerably slowing down the public's understanding of how AIDS can be transmitted.

Second, the conservative politics of the middle and late years of the Reagan Administration attempted to thwart my attempts to educate the public about AIDS and tried to stir up hostility toward its victims. I tried to rise above the politics of AIDS, but it would cost me many friendships. Just to keep you informed about what was happening in science elsewhere, in May 1983, Robert Gallo of the National Institutes of Health and Luc Montagnier of the Pasteur Institute in Paris, identified the infectious agent that caused AIDS: A virus dubbed HIV-III or Human Immuno Deficiency Virus. In early 1984, there were over 5,000 reported cases of AIDS with 2,300 deaths. In spite of all that I've said there was no public outcry or any outcry even from organized medicine for more and appropriate leadership from the government. In 1985, as the Public Health Service and other branches of the medical community learned more about AIDS, they provided a weapon in this struggle against this strange disease: a test to identify the presence of antibodies to the HIV virus in the blood supply.

In spite of the confusion, frustration, anger, and ignorance, the government did press forward and make astounding advances in medical science

and research. We learned as much about AIDS in six years, as we had learned about polio in forty. It was a testament to these unflagging efforts that a reliable blood test was discovered and made generally available as early as the fall of 1985.

That test changed a lot. The odds of getting an AIDS contaminated unit of transfused blood fell from between 1 in 40 thousand, to 1 in 250,000. Compare those odds with say, death on the highway 1 in 5,900.

Dr. Tony Fauci, later to direct AIDS research at the National Institutes of Health, insisted we check out any study that did seem to rule out the spread of AIDS by casual contact. Gradually, a convincing body of research led us to some important conclusions, because of that we stressed four important conclusions about AIDS:

It was fatal
It was spreading
It was transmitted mainly by certain specific
behavior involving sex and/or drugs
There was no cure.

Ed Brandt, the Assistant Secretary for Health, had left the administration to go to the University of Maryland as Provost on the Baltimore campus and had been succeeded by James O. Mason as Acting Assistant Secretary for Health. Mason made me a member of the AIDS Task Force. He and I also agreed that AIDS demanded a clear spokesperson, and I could make any statement I thought appropriate. At last, I could speak up.

Meanwhile, I was preparing the report the President had requested, and I met with 27 distinct groups representing AIDS advocacy, business, education, health, labor, public officials, and religion . . .

Without representatives from the aforementioned groups, there would have been no AIDS report. I needed to be in touch with all of the national groups that were concerned about AIDS. I wanted to make sure they knew what I was doing, and I wanted none to say, after the report was published that they had been blindsided or kept in the dark.

Maintaining control of the report, keeping the circle small, meant that I would have only a very small staff to help me. Dr. Michael Samuels brought with him a broad background of public health endeavors, and he also brought the part-time help of Jim McTigue, a commissioned officer with whom Mike

and I had frequently worked on intergovernmental affairs. We were supported by a small team: the Assistant Surgeon General, Jim Dixon; and Edward Martin, my Chief of Staff; my Deputy Director of the Office of International Health, Hal Thompson; my personal assistant, Stephanie Stein; and of course, my Deputy Surgeon General, Faye Abdelluh.

The information provided by the National Hemophilia Foundation was critical. We had more information on hemophiliacs and their behavior while infected with HIV, than we had on any other group. Their infection, of course, had come from contaminated blood and blood products used in the treatment of their disease.

I found the people from the Southern Baptist Convention to be delightful, but very naive about AIDS. I think they were shocked by what we had to tell them, about how the virus was sexually transmitted. I thought they might be uncomfortable with a mandate for sex education I planned to mention in my report, so I challenged them to write their own sex education curriculum for their twenty-six million constituents. To their credit, within six months of our chat, they did what I had suggested, and I had the pleasure of giving their annual convention's keynote address when they announced their curriculum on human sexuality.

I released the report on Acquired Immuno Deficiency Syndrome that the President had asked me to write, on October 22, 1985. It is amazing that this was five years and four months from the first internal discussion of AIDS by the Public Health Service in the Humphrey Building on Independence Avenue, in June of 1981.

There is a story about my presentation of the report to the Cabinet that appears no place else that I know of, except in my autobiography. We had ordered a huge supply of this document on the cheap stock that the government usually uses for such reports. My concern was that when I presented the report, some members of the Cabinet would ask that changes be made too "soften" the language. Inasmuch as I felt that specific language was essential to my mission, I devised a plan to present each of the Cabinet, not with a cheap paper report, but one on glossy paper, bound with a cover in royal blue (the Public Health Service color), and imprinted with the title and the great seal of the Public Health Service in silver. My

hope was that they would assume the report was so expensive that they would not suggest that the thousands upon thousands that had already been printed be scrapped, in order to make a few words changes. I was right, and no changes were made. The report was presented to the public by way of a press conference the following morning, October 22, 1985. A copy of the report follows, which will lend credence to the lectures that follow.

In the lectures that follow, there will be a sampling of the talks I gave on AIDS beginning with January 15, 1987 and progressing on for the next several years. Because, in this archive, all the AIDS speeches will be together, each introductory page for each individual lecture will only cover matters pertinent to that lecture, which have not been covered in previous introductory material. The reader will also know how much time elapsed since the last report by lecture to the public, and in that way, the reader will understand that lectures are given in close sequence, not much increase of knowledge. However my presentation changes depending upon the venue, the audience, and the past history of that audience in reference to AIDS.

The report that was given by me in 1985 to the American public still stands pretty much today as truth. The exceptions are these: we now know that all people are not equally susceptible to infection by the virus, but we can measure who they are, and the treatment has been refined greatly. In many of the early lectures I mention treatment with AZT, (Zidovudine, formerly Azidothymidine), which I said, merely prolonged life. We now know that that's all any treatment can do, because thus far, AIDS is not curable, and we are still without a vaccine. However, with proper treatment, started early, it is possible, probably to live out one's normal life expectancy and die of other causes.

In any lecture, especially by a government officer, it is the question and answer time that is more important. It is the most stressful and demands the greater depth of knowledge.

The report was written for American consumption, although it was used by a number of foreign countries when it was published, either in whole or in part, and was the template that served in the writing of the British report to its own people.

This introductory writing is being undertaken in the winter of 2002–2003, when the world faces

genocide from AIDS in some of the countries of Africa and Asia. In these countries, poverty, sexual custom, lack of databases, denial, illiteracy and poor health education, as well as faulty government policy contribute to the terrible scourge that AIDS has

become in the developing nations. Money can't fix it all, but it would go a long way to help.

Source: National Library of Medicine (NLM). <https://profiles.nlm.nih.gov/ps/retrieve/Narrative/qq/p-nid/87/p-docs/true>, accessed September 25, 2018.

Apple

Apple Inc., is an American technology company that designs, develops, and sells consumer electronics, computer software, and online services. With \$1,300, Steve Jobs (1955–2011) and Steve Wozniak (1950–) founded Apple in 1976. Although both men were knowledgeable in electronics and possessed the ability to innovate, Jobs's major strength was his gift for envisioning future technological possibilities, while Wozniak excelled in making some of those dreams a reality. After years of vision, hard work, and ingenuity, a business begun in a garage grew to be one of the world's largest technological corporations.

Early on, Apple's main competitor was International Business Machines (IBM), a major seller of various types of machines for the office. In the 1970s, the personal computer (PC) for the home was almost universally considered a high-tech toy. In like manner, people who bought PCs were usually seeking to engage in a technology-related hobby. The duo built and sold 250 Apple I (hobby machines) out of Jobs's garage for \$666 each. However, Jobs had a much grander vision for Apple PCs. If Apple could find a way to integrate PCs into people's daily lives, he believed, PC technology would become indispensable at work and at home. Consequently, Apple engaged in a marketing campaign that showcased the educational value of PCs for young children. Apple also developed computer software to promote problem-solving skills and creativity. Many schools and parents purchased PCs for their children. In fact, many educational leaders rewrote state K-12 curriculum standards to reflect a need for the use of technology in the classroom.

Apple's strategy of marketing the PC as an educational boost for young children had two major benefits. First, it led to the sale of millions of PCs. Second,

by assimilating the young to computers, Apple secured a future computer-literate consumer base. Sales could also be generated with continual innovation. As new computers with more advanced hardware and software rolled off the factory floor, older computers and older software would become obsolete. If innovations were significant enough, consumers would keep upgrading.

With Apple II and Apple III, profits were so great that in 1980 (just four years after the company's establishment), it was converted to public ownership. Although Jobs and Wozniak gave up ownership of Apple by going public, they enjoyed great monetary rewards. The new Apple chairman, Mike Markkula, hired Mike Scott as president. Jobs functioned as a consultant and Wozniak as an engineer. Scott left Apple after one year. Consequently, Markkula assumed the presidency, and he promoted Jobs to chairman.

In 1982, Apple became the first PC company to reach \$1 billion in annual sales. In 1983, Apple challenged IBM with the Lisa, a new business machine. Jobs hoped to gain an edge in the business market with Lisa's more user-friendly mouse, pointer, and computer screen, but Apple was unable to break IBM's hold on the business market. Due to low Lisa sales, Apple's stocks fell to half their value. In spite of the failure, Jobs pressed on with the Macintosh ("the people's computer"), which made use of all of Lisa's innovations but was sold at a fraction of Lisa's cost.

Jobs believed that Macintosh's ease of use and two-disk memory drive gave it a tremendous advantage over all other PCs on the market. In fact, he was convinced that anyone who tried it would buy it. Macintosh sold very well the first year, but sales faltered after that. In 1985, John Sculley assumed the

presidency after a management shakeup that caused the departure of Jobs and several other Apple executives.

During the 1990s, Sculley expanded Apple from a school and home PC maker to a business computer company. In addition, Apple's focus was on providing consumers with more powerful machines, including the PowerBook (1991). However, low profits led to Sculley's dismissal in 1993. President Michael Spindler generated quick short-term profits by licensing Apple technology to outside firms. Unfortunately for Apple, this resulted in a market flooded with Apple clones, which dramatically drained Apple's long-term profits.

According to analysts, during these years, Apple's bad fortune was more closely tied to mismanagement than a lack of technological innovation. For example, Power Macintosh (Power Mac) computers, which were released in 1994, were highly sought after. However, executives grossly underestimated the demand for the product, and by 1995, Apple had \$1 billion of orders it could not fill. By 1997, the company's stock was trading at only \$14 per share (compared to \$70 per share in 1991).

In 1996, Apple acquired NeXT (Steve Jobs's company) for \$377 million. As part of the negotiations, Jobs agreed to return to Apple as a special advisor. In 1997, Jobs was named interim chief executive officer. He regretted that Apple computers and related computer software had fallen out of favor with the public. In 1998, he unveiled the iMac, an all-in-one, colorful computer that showed off Apple's skill with design and functionality. Although sales spikes were modest compared to the company's prior glory days, Apple's profits steadily improved. In fact, by the end of 1999, Apple's stocks sold for \$99 per share. By 2000, Jobs was firmly in command as chief executive officer (CEO). In the 2000s, Apple saw even greater growth with the sale of smaller and more personal devices.

In 1979, the Sony Corporation had unveiled the Walkman TPS-L2, a portable cassette tape player with headphones, which became one of the most popular consumer items of the 1980s. Jobs dreamed of a less bulky digital device to rival the Walkman, and he challenged Wozniak to develop it. But, even by the 1990s,

the technology to produce a quality product of this type did not exist. It was not until 2001, when Toshiba unveiled a 1.8-inch hard drive, that developers were able to realize Jobs's vision. In 2001, Apple released the iPod, a digital music player with five gigabytes (GB), which allowed for the storage of about 1,000 songs.

The next year, Apple released a 10 GB model. Then, iPods were released in assorted sizes and colors. In 2005, Apple released a video iPod, the fifth generation of the device. By that year, total iPod unit sales had reached 30 million, and iTunes (Apple's online digital download store) sold music, videos, and audiobooks.

In 2007, Jobs unveiled the first iPhone (a touch screen-controlled mobile phone with Internet capabilities). In the first 200 days after its release, Apple sold 4 million iPhones. By 2009, 30 million iPhones had been sold worldwide. Usually, each succeeding generation of iPhone featured some sort of improvement (including a faster 3G network connection speed, a wider screen, and more useful applications). Jobs unveiled the iPad, a portable computer tablet, in 2010, and iCloud (storage and synchronization of digital content across computers, iPhones, iPads, and iPod Touches) in 2011.

By the 2000s, some of the products that Apple produced, including smartphones and computer tablets, had caught up technologically to gadgets previously only imagined by science fiction writers. Apple had become one of the biggest corporations in the world. Like other corporate giants, Apple had its share of controversy. For example, like several other major U.S. companies, Apple had most of its products assembled in China, where low wages and dangerous working conditions were the norm. In China, managers placed enormous time pressure on employees. In one factory, suicide attempts were so high one year that factory managers placed safety nets around the buildings to try to prevent jumpers from dying.

In 2011, 64,000 Silicon Valley workers filed a class action suit against Apple and other technology companies, charging that they had agreed not to recruit each other's employees. Also, some Apple executives resigned after they were accused of illegally backdating stock (buying Apple stocks at past, lower prices).

Since 2012, Apple CEO Tim Cook was embroiled in a congressional investigation concerning charges of Apple’s tax evasion.

In spite of these and other problems, for the most part, the general public remained loyal to Apple. The public loved Apple products, which had become status symbols. Some people stood in line for days to buy the newest iPhone. Most of all, the public had come to trust Jobs’s talent for technological innovation. Even though Apple sales were strong in 2011, stocks fell immediately after Jobs’s death from cancer, because many people wondered just how innovative Apple would be without him. Apple’s story illustrates how innovation is only possible when the right vision converges with the right type of technology.

Rolando Avila

See also Computer/Information Technology; Dell, Michael “Saul”; Gates, Bill; Internet; Jobs, Steve; Microsoft; Personal Computer (PC); *Vol. 3, Sec. 3*: iPod; Smartphone and 3G Network

Further Reading

Frieberger, Paul, and Michael Swaine. 1984. *Fire in the Valley: The Making of the Personal Computer*. Berkeley, CA: Osborne-McGraw-Hill.

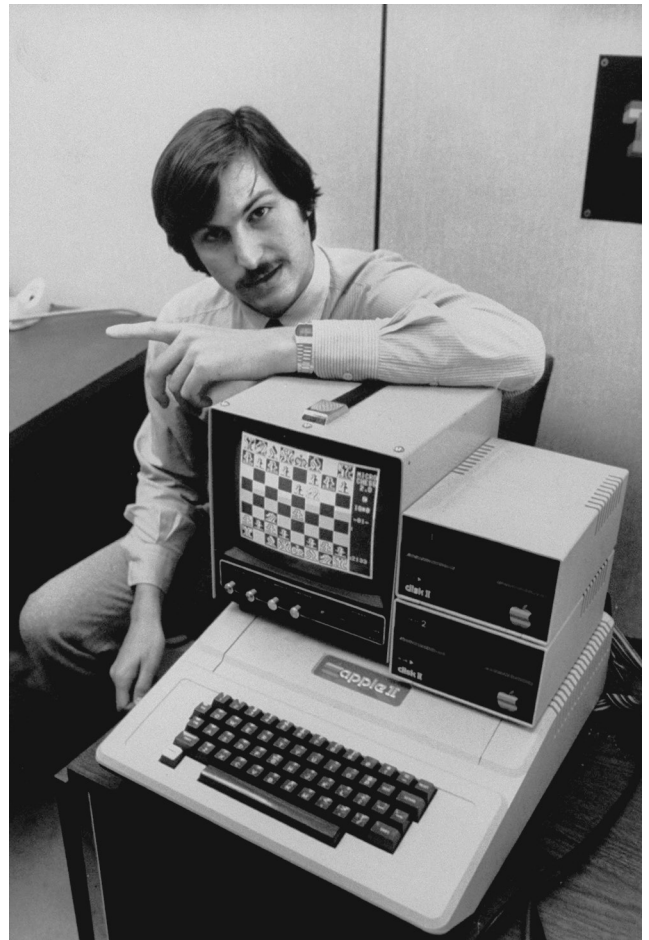
Molina, Brett. 2017. “The 10 Biggest Moments in the History of iPhone.” *USA Today*, January 9. <https://www.usatoday.com/story/tech/news/2017/01/09/10-biggest-moments-history-iphone/96337396/>, accessed August 31, 2018.

Price, Rob. 1987. *So Far: The First Ten Years of a Vision*. Apple Computer Tenth Anniversary Publication. Cupertino, CA: Apple Computer.

Seitz, Patrick. 2005. “Apple Sees Healthy ‘iPod Economy.’” *Investor’s Business Daily*, December 5, A5.

Apple II

In the 1970s, the personal computer was introduced to the home market. Prior to the 1970s, computers were advertised mostly to businesses. The Apple II is considered to be Apple Computer’s first successful computer, and it created the company’s philosophy of simplicity. Today, Apple is known as a worldwide



Apple Computers cofounder Steve Jobs poses with the Apple II computer, 1979. Jobs and associate Steve Wozniak helped launch the computer revolution, which grew into the cell phone revolution within 20 years. (Ralph Morse/Time Life Pictures/Getty Images)

technology brand. Many people credit the Apple II for elevating Apple as one of the top tech companies globally.

During the 1970s, there were only two other major computer products, Commodore’s PET 2001 and Radio Shack’s TRS-80, in the personal computer market. Established in 1976, the Apple Computer company, formed by Steve Wozniak and Steve Jobs, focused on the home market and introduced the Apple II at the West Coast Computer Faire, a tech event hosted in San Francisco, California.

Like its competitors, the Apple II was one of the first computers with a color display. It also came with a built-in BASIC programming language. To make

things even more user-friendly, it was ready to run as soon as it was turned on. The Apple II is referred to as the first user-friendly computer system. The insides of the Apple II were essentially designed by Wozniak. Jobs is often praised for his contribution in the aesthetics of the Apple II (and all future technology that came from the company, including the iPod, iPhone, and iPad).

One thing that separated the Apple II from its competitors was its eight expansion slots. No other computer had yet to offer this feature or option. The top of the computer was also detachable, which made modifying the hardware much easier for the skilled computer aficionado. In 1979, Daniel Fylstra, a computer programmer, created VisiCalc, a computer application for the Apple II. This application was used to do business calculations and to forecast finance. This application made the personal computer a tool for people who did not know how to create applications. VisiCalc's success correlated with the Apple II's unit sales.

The Apple II's price was \$1295, and it sold 35,000 units in its first fiscal year. The company would continue to flourish throughout the years. Apple ultimately became the first personal computer company to reach \$1 billion annual sales in 1982. The Apple II revolutionized the target audience for computer companies. They no longer focused solely on business customers; the market expanded to every single person.

Today, the Apple II is no longer manufactured due to various innovations created by Apple, but it was the cornerstone for the success and philosophy of the company. Many of today's Apple products continue to take the "simplicity" approach pioneered by the Apple II.

Victor Anguiano

See also Apple; Jobs, Steve; Personal Computer (PC); Wozniak, Steve; *Vol. 3, Sec. 3*: iPod

Further Reading

Apple. 1977. "Introducing Apple II." *Modern Mechanics*. September. <http://blog.modernmechanix.com/introducing-apple-ii/>, accessed August 31, 2018.

Craddock, David L. 2017. *Break Out: How the Apple II Launched the PC Gaming Revolution*. Atglen, PA: Schiffer.

Weyhrich, Steven. 2013. *Sophistication & Simplicity: The Life and Times of the Apple II Computer*. n.p.: Variant Press.

Artificial Heart

An artificial heart is a mechanical device designed to replace a human heart. A reliable synthetic heart is considered the "holy grail" of medical science. In 1982, a team of doctors implanted a Jarvik-7 artificial heart into Barney Clark, who then lived for 112 days. This is considered the first successful artificial heart transplant. Today, artificial hearts are generally considered for patients unsuitable for human heart transplants. The ventricular assist device (VAD) operates similarly to the artificial heart but is not meant as a heart replacement. VADs are now commonly used in cardiac surgeries.

Russian Vladimir Demikhov transplanted a mechanical heart into a dog in 1937. Demikhov later became famous for his dog head transplants, which resulted in two-headed dogs. In 1949, William Sewell and William Glenn successfully applied a bypass procedure to a dog's heart, and in 1957, Willem Kolff performed an artificial heart transplant on a dog, though the dog only lived 90 minutes after the surgery. Kolff became one of the most prolific artificial heart transplant scientists of the 1960s and 1970s. He had some success implanting artificial hearts into cows in the 1970s using hearts of his design and then using Robert Jarvik hearts. The National Institutes of Health established an artificial heart program in 1964 that aimed to successfully implant an artificial heart into a human within 10 years.

In the 1970s and early 1980s, Robert Jarvik designed a number of artificial hearts with his mentor, Willem Kolff. The Jarvik-7 was, like previous artificial heart models, a self-contained, pneumatic mechanism. The heart's control mechanism, which was as large as a small household stove, was attached to the heart with pneumatic tubes that ran through holes in the patient's chest. Thus, while better than previous heart designs, the Jarvik-7 limited patient mobility and carried a high infection risk.

Artificial heart models in the 1980s continued to rely on large, exterior pumping mechanisms and

power sources. By the 1990s, researchers had begun developing smaller artificial hearts. In 2001 a two-pound, rechargeable-internal-battery-operated heart called the AbioCor was successfully implanted. Though smaller than earlier hearts, the AbioCor is too large to be used on anyone but larger men. It has a lifespan of one to two years and is considered suitable only for critically ill patients ineligible for human heart transplants.

In 2011, a Frazier-Cohn heart, which had been successfully transplanted into sheep, was transplanted into Craig Lewis at the Texas Heart Institute. The heart extended Lewis's life for 5 weeks before he succumbed to liver and kidney failure. Artificial heart researchers are currently working on a soft artificial heart made from silicon with a 3-D printer. The heart is meant to look and function like a real human heart. In 2017, research was still preliminary.

Ventricular assist devices, or VADs, are related to but different from artificial hearts. VADs are not meant to replace hearts but to assist failing hearts. Argentine American Domingo Liotta invented the first VAD and is thus considered one of the great innovators in cardiac surgery and cardiac prostheses, including artificial hearts.

Critics point out that there has never been a truly successful artificial heart despite decades of research and millions of dollars of investment. Rather, artificial hearts are emblematic of medical research that regards all human body parts as replaceable while ignoring the human suffering caused by research and testing.

Peg A. Lamphier

See also AIDS Research; Insulin Pump; *Vol. 3, Sec. 3:* Human Genome Project

Further Reading

McKellar, Shelley. 2017. *Artificial Hearts: The Allure and Ambivalence of Controversial Medical Technology*. Baltimore: Johns Hopkins University Press.

Artificial Intelligence (AI)

A modern definition of artificial intelligence (AI) is intelligence exhibited by a machine, created using a

combination of approaches and software tools, to implement an intelligent agent that can store and use knowledge obtained through perception, deduction, and reasoning to implement problem solving, planning, and learning that may control the movement of people and the manipulation of objects. Early efforts in creating AI centered on one approach or software tool but were found to be of limited usefulness. Modern AI systems are composed of a combination of approaches and software tools and more closely resemble what humans would view as intelligent.

The general problem in creating AI can be broken down into several subproblems:

1. Deduction, reasoning, and problem solving
2. Knowledge representation
3. Planning
4. Learning
5. Natural language processing
6. Perception
7. Motion and manipulation

Due to the complexity of the problems in AI creation, there have been many different approaches, with varying degrees of success. For instance, a logic approach is not easily applied to the perception problem domain. This has been somewhat rectified by combining approaches. However, some of this disappointment is due to the problem of the AI effect: after a technique is perfected, observers no longer consider it to be true artificial intelligence. Even a computer that can beat a chess champion is viewed as only performing calculations.

The following is a list of some of the approaches to AI:

- *Cybernetics and Brain Simulation.* One of the early approaches to AI was an attempt to simulate the action of neurons that control and use information to then control systems. The approaches known as “computational neuroscience” and “cybernetics” were largely abandoned by the 1950s. However, more recently, with the advent of more computing resources, neural networks have seen success in computer vision and speech recognition through deep learning systems.

- *Symbolic.* Symbolic AI became the focus of most researchers in the 1950s. Allen Newell and Herbert Simon thought that general, intelligent action could be realized using symbols and their associated processes, which are described using expressions. This line of thought resulted in an attempt to produce systems using different symbols, processes, and expressions. Cognitive simulation was used to describe the processes and expressions that the human mind uses to give meaning to symbols. Some used logic to describe the processes and expressions, which resulted in the Prolog programming language. Some rejected the use of generalized processes and expressions, creating a custom process for each solution.
- *Subsymbolic.* By the 1980s, it had become obvious that symbolic AI was not producing useful AI. Researchers began to imagine systems where there was no specific representation of knowledge. Rather, machines should be able to discover knowledge. The discovery of knowledge can be made by evaluating a large number of generated solutions and choosing the best one. For instance, genetic programming seeks to define a random initial set of individual solutions, which are associated with a metric for rating their success in solving the problem. Subsequent generations are created by selecting the best individuals from the current generation and then making some random changes to their solution. This process is continued for a number of generations before the best result is selected as the final solution.

Fuzzy logic systems function by first categorizing inputs into concepts (linguistic classifications) and then performing calculations on the concepts and evaluating the result. Fuzzy logic systems are often used as control systems. Recently a fuzzy logic system called ALPHA has been tested for controlling unmanned combat aerial vehicles and has been found to be extremely effective.

The high number of inputs and outputs to be considered by ALPHA was handled by a new AI tool: the genetic fuzzy tree (GFT). The GFT solves the problem of a large number of variables by creating a collection of fuzzy inference systems (FISs) that can run in

parallel. The FISs classify the inputs and outputs into a linguistic classification, which reduces the runtime work and allows for easy programming of the system by knowledge experts.

ALPHA is a genetic fuzzy system where a genetic algorithm creates all of the components of the controller multiple times. Each automatically generated version of ALPHA competes against a manually tuned version of ALPHA to determine if it is better. Eventually, one version of ALPHA is chosen as the best. This method has seen success in the realm of AI.

In the 1990s, the use of statistics and sophisticated mathematical tools became important in the discovery of solutions to problems. Many problems in reasoning, planning, learning, perception, and robotics have incomplete or uncertain information. Mathematical tools like probability theory and economics help to solve these problems. Statistics help a deep-learning neural network classify objects and recognize words.

The varied approaches to AI have been used alone or in combination in ways that have been identified as general AI tools used to solve problems. These classes of tools may be used to solve different problems. Some of the problems and the class of tools used to solve them are listed in the following table.

Problem	Tool
Find the best solution	Search and Optimization
Control systems	Genetic Fuzzy Tree
Represent knowledge and solve problems. Learning.	Logic Programming, Prolog
Solve problems with limited information	Probabilistic Algorithms
Learn with limited information	Statistical Learning
Computer vision, speech recognition, natural language processing	Deep Learning Neural Networks

For individual tools, one may combine different approaches to create the best AI tool. For example, neural networks and genetic programming can be

combined to produce the best tool. Under this scenario, several neural networks with number of nodes, weights, and connections are the initial individuals that are subsequently evaluated, selected, and modified for future generations. After several generations, a particular neural network is identified as the best according to the associated metric (for instance, how well the neural network is able to identify objects). In other implementations, one could use logic programming on fuzzy logic facts or use a sophisticated mathematical tool to define a genetic programming metric.

The implementation of AI at the system level usually relies on a combination of approaches and tools. While one approach or tool may solve a specific problem (like providing a control system to an unmanned aerial vehicle), systems usually solve several problems simultaneously. Many combinations of neural, symbolic, subsymbolic, and mathematical approaches and tools may be needed when designing and implementing an AI system.

For systems, researchers find that they may need to combine several AI tools. For instance, an unmanned aerial vehicle needs AI to control the aircraft using a genetic fuzzy tree, but it also needs to understand its surroundings through computerized vision tools implemented using deep learning neural networks. One can imagine that probabilistic and statistical learning algorithms could be helpful in the competitive and unpredictable environment of a battle.

AI systems are composed using AI approaches and AI tools; however, due to the AI effect, many of the systems are not viewed as true artificial intelligence systems. The AI effect has been described as occurring when an AI tool or system becomes commonplace. The result of the effect is that observers may complain that the system is only performing simple calculations and is not a “true” AI.

The number of application domains where AI is being used is growing rapidly. Some success stories for AI have been found in the following:

- Fraud protection systems to counter the unauthorized use of credit cards
- Natural language processing for online and telephone automated assistance

- Computer-assisted interpretation of medical and satellite images
- Toy robots and video games
- Autonomous airplanes and cars
- Industrial robots
- Computer-generated news and reports
- E-mail spam filtering
- Investment decisions

The following ethical concerns surround artificial intelligence:

1. Are intelligent machines dangerous?
2. Can intelligent machines have a consciousness in the same way that a human does and therefore deserve certain rights?
3. Can or should machines be programmed to make ethical decisions? How does a biased human programmer affect the bias of the machine?
4. Should intelligent machines reduce or eliminate human jobs?

While most discussions of ethics may be premature given the limited abilities of intelligent machines, there are many people and groups talking about how to keep AI ethical. Bill Gates, Stephen Hawking, and Elon Musk have all voiced concerns about the potential threats from AI. As scientists and engineers develop more and more artificially intelligent machines, they will increasingly integrate into human lives. Ethical concerns should only become more important as AI becomes even more common and increases in sophistication.

Mei B. Klein

See also Open-Source Software; Personal Computer (PC); *Vol. 3, Sec. 3: Linux*

Further Reading

- Boden, Margaret A. 2016. *AI: Its Nature and Future*. Oxford: Oxford University Press.
- Fogel, David B. 1998. *Evolutionary Computation: The Fossil Record*. New York: Wiley-IEEE Press.
- Mueller, John Paul. 2016. *Machine Learning for Dummies*. Hoboken, NJ: John Wiley & Sons.

Bath, Patricia. See Laser Cataract Surgery Device

Berners-Lee, Tim (1955–)

Tim Berners-Lee is the mind behind the creation of the World Wide Web used by millions around the world at any given time of day. His innovative idea made the complicated process of sharing information via computer an easy task. An Englishman by birth, Berners-Lee's invention changed the world.

Berners-Lee was born in London, England, on June 8, 1955. Both his father, Conway Berners-Lee, and his mother, Mary Berners-Lee, were mathematicians. His parents' career path would be of great influence growing up: Berners-Lee constructed a device that allowed him to control his model trains. This interest in the field of electronics and mathematics followed him into adulthood, and he graduated with a bachelor's degree in the field of physics from the Queen's College at Oxford University in 1976. Then he worked for a variety of firms in Britain, including the major telecommunications firm Plessey Telecommunications, for about two years.

Berners-Lee then worked for Conseil Européen pour la Recherche Nucléaire (CERN), a laboratory in Geneva, Switzerland, that concentrates on particle physics. Though his stay at CERN was not very long, he did some important experiments there. To document his work and personal life, he used Enquire, a software program that he wrote that used "hypertext," which allows one text document to be linked to several others at once. Berners-Lee used that idea to experiment with on his own computer. The Enquire program slowly made its way to the computers of many other scientists working for CERN. Though many were open to the concept, some were not.

After six short months with CERN, Berners-Lee made his way to Image Computer Systems, an English firm, in 1981. There, he designed hardware and communications software for printers for three years. But he was invited back to CERN to perform further research and returned in 1984. The firm had ceased to work with Enquire, but it appreciated and recognized his innovation and knowledge. At CERN, Berners-Lee

experimented and proposed ways to use the concept of hypertext to allow people to obtain and share information.

In 1990, Berners-Lee's ideas became a reality. With the assistance of those from CERN, he developed hypertext transfer protocol (HTTP), hypertext markup language (HTML), and the uniform resource locator (URL). Each component was of high importance, working together to allow the emergence of the World Wide Web. The purpose of the hypertext transfer protocol was to better organize information that was to be viewed or shared, by proper storage. Hypertext markup language (HTML) essentially categorizes the different types of information in any document, such as images or text. And last is the uniform resource locator (URL), which can be best described as a code or address given to a certain document that can be easily referred back to when needed. Berners-Lee wanted everyone to have access to information, which led him to create what is now known as the World Wide Web. In October 1990, those within CERN were the only ones who had access to it.

In summer of 1991, Berners-Lee finally allowed public access to the World Wide Web. At first, Berners-Lee provided a document that taught the public step by step how to set up a Web server as well as to how to set up a site of one's own. It had a slow start initially, but it picked up very quickly once word spread. Later, many approached him about making a profit from such an innovative, world-changing invention, but he declined them all. He recognized that it was not perfect, so in 1994, he founded the World Wide Web Consortium (W3C) to enhance and improve it. As a senior researcher and holder of the founder's chair at the MIT Computer Science and Artificial Intelligence Laboratory (CSAIL), Berners-Lee is also a member of the advisory board of the MIT Center for Collective Intelligence. In 2011, he joined the board of trustees of the Ford Foundation. Ten years later, he found himself being knighted by Queen Elizabeth II, and he would continue to receive recognition for this life-changing invention.

Berners-Lee did not look to profit from the World Wide Web; neither does he want anyone else to. He wants it to be open for everyone to use. He will not allow any entity to censor or interfere with that right.

The Web is a very powerful tool that has changed the way we all think and approach information gathering and sharing.

Dannela Azul Valencia

See also Internet; *Vol. 3, Sec. 3: Hypertext*; Negroponte, Nicholas

Further Reading

Berners-Lee, Tim. 2000. *Weaving the Web: The Original Design and Ultimate Destiny of the World Wide Web*. New York: Harper Business.

Fensel, Dieter, et al., eds. 2005. *Spinning the Semantic Web: Bringing the World Wide Web to Its Full Potential*. Boston: MIT Press.

Hillstrom, Kevin. 2005. *The Internet Revolution*. Detroit: Omnigraphics.

Boston Tunnel

The Boston “Big Dig” tunnel is one of the largest infrastructure projects in the United States today. Known officially as the Central Artery Project, the Big Dig commenced planning in 1982 to aid heavy traffic congestion on the city’s main highways. As vehicular presence rapidly grew in the 1990s, the deteriorating six-lane central artery, Interstate 93, could no longer uphold the swell of activity. Traffic was heavy for more than half the day, and the accident rate was the highest national average of all urban areas—nearly quadruple. By 2010, this severity was estimated to cost motorists \$500 million annually in wasted gas, accidents, and late service charges. Consequently, Boston’s economy suffered greatly and was in need of transportation improvements.

Under the oversight of the Massachusetts Turnpike Authority, construction began in 1996, and the project was completed in 2007. The Big Dig had two main goals components: to restructure the overhead central six-lane system into a multilane underground tunnel named the Thomas P. O’Neill Jr. Tunnel, which crosses the Charles River; and the extension of Interstate 90 from South Boston to Logan International Airport through the construction of the Ted Williams Tunnel.

The project also included the construction of a 10-lane hybrid bridge named the Leonard P. Zakim Bunker Hill Bridge and the Rose Kennedy Greenway. Once the tunnel was commissioned, the Authority began demolition on the old Central Artery to free up space and use the area for future development.

Due to the specifications of relocating an elevated highway into a tunnel, the Big Dig became one of the most daunting and expensive projects in the nation’s history. No project of this stature had ever been undertaken in a significantly dense and urban area. In its entirety, the Big Dig cultivated 161 miles of lanes, half of which were in tunnels and roughly eight on highways. Sixteen million cubic yards of soil had been excavated from the site, while 3.8 million cubic yards of concrete were installed. Concern grew regarding the elevated highways and the masses of newly installed concrete. Engineers decided to excavate farther under the tunnel and place 26,000 feet of steel-reinforced slurry walls, the largest amount ever used in North America. These structures served as walls for the tunnel while also aiding the construction of the highways above.

Initially, the Big Dig was estimated to cost around \$2.6 billion and was planned to be completed in 1998. However, several delays, design flaws, leakages, and a fatal ceiling collapse heavily prolonged the project’s duration and costs. At its peak from 1999 to 2002, the project cost around \$3 million per day or \$110 million per month, with 5,000 workers on-site. Upon its completion in 2007, the cost for the Big Dig totaled over \$14.6 billion—significantly higher than expected. It was the most expensive highway super project in American history. Over \$400 million was paid in restitution by the overseeing engineering consortiums, Bechtel and Parsons Brinckerhoff, for injuries as a result of various structural mishaps.

Further obstacles also arose in regard to the site’s environmental impact. Agencies were concerned that with extraction of landfill and earth, several toxins would be released into the atmosphere. This would disrupt the habitat of several million rats, causing them to seek new residence in streets and homes. Also, to remove tons of landfill, excavators needed to freeze the ground to extract it more efficiently. This posed an environmental issue because the contaminated fill

allowed more toxins to be released into the atmosphere instead of the lesser amount via traditional and safer methods.

On July 10, 2006, a fatal collapse occurred within the confines of the Ted Williams tunnel. A 26-ton panel off the tunnel's ceiling fell, leaving one woman dead and another injured. Outrage erupted after this tragedy, as it stemmed from a major design flaw and reflected poorly on the engineers responsible. Despite the project's \$14.6 billion cost, cheap and improper adhesive had been used to hold the panels on the ceiling. Settlements were reached in response to the families of both the injured and deceased, while the state of Massachusetts launched a civil suit against the aforementioned Bechtel and Parsons Brinckerhoff. The adhesive supplier, Power-Fast Epoxy, was indicted on the charge of involuntary manslaughter.

Apart from legal action, investigation and repairs decommissioned the tunnel for almost a year, causing Boston's traffic to congest once again. It was also mentioned that a heart attack victim lost his life due to traffic jams as he proceeded toward Boston Medical Center. Other issues involved severe leaks and light fixtures that were prone to collapse. The guard rails in the tunnels were also recalled due to their squared edges, which were responsible for impaling several who had been ejected from their cars in the midst of accidents. After the eighth incident, the Massachusetts Department of Transportation removed a portion of the dangerous rails.

After the Central Artery Project's development, Boston's transportation and quality of life drastically improved. The city saw a 62 percent reduction in the vehicle-hours to travel on the new highways, saving Bostonians and visitors around \$168 million annually. The city also saw a 12 percent decrease in its carbon monoxide levels and recycled the excavated dirt to top landfills. Neighborhoods were able to reconnect in the absence of the former highway. In the highway's stead, the project generated more than 300 acres of parks and green space. Several of these acres are planned to be developed into residential and retail communities.

Kyle Soren

See also *Vol. 2, Sec. 1:* Brooklyn Bridge; *Vol. 2, Sec. 3:* Golden Gate Bridge

Further Reading

McNichol, Dan, and Andy Ryan. 2000. *The Big Dig*. n.p.: Silver Lining Books.

National Academy of Engineering. 2003. *Completing the "Big Dig": Managing the Final Stages of Boston's Central Artery/Tunnel Project*. Washington, D.C.: National Academy Press.

CD and DVD

Compact discs and digital versatile discs, known by the shorthands "CDs" and "DVDs," are data-storing devices containing media read by laser. While the two types of discs are fundamentally similar, there are some key differences between them. CDs have a slight structural difference, lower storage capacity, and slower rotation speed than DVDs. DVDs possess the benefit of not degrading each time they are read, allowing a longer lifespan. CDs and DVDs were the mainstream way of delivering multimedia to people across the globe for many years. However, wireless and discless methods of transmitting data, such as streaming, have gained momentum and popularity in the modern age due to efficiency, ease of use, low cost, and perpetually growing libraries of media.

While the creator of the compact disc cannot be credited to any one entity, James T. Russell, an American inventor; Sony; and Philips are key figures in the creation of the CD in circulation today. Sony and Philips, international electronic companies, began creating and refining the compact disc in the late 1970s, a decade after it was originally created by Russell. Through cooperation with Sony, the final diameter was 12 centimeters, and the initially proposed resolution (accuracy) of 14 bits was increased to 16. CDs were wildly popular in the 1980s, when they were first introduced to the public, and well into the 2000s because they were affordable and accessible as they transported media, graphics, and other electronic information efficiently.

Different versions and capabilities of compact discs were developed since the original inception of the first compact disc known as a CD-ROM. While structurally similar, the types of CD differ mainly in their recording and rewriting capabilities as well as storage capacities.



Introduced in the 1980s, compact discs (CDs) offered data storage technology that took up less physical space and was a higher quality option compared to earlier data storage technology. CDs replaced floppy discs and DVDs replaced VHS tapes. CDs were replaced by flashdrives within ten years. (Corel)

The “compact disc read-only memory” (CD-ROM) is neither recordable nor rewritable once the original data is loaded onto the disc. Once its maximum capacity is reached, the disc is considered full and is unable to accept any more data. This type of disc has been a popular choice for video game and software companies for distributing their media to consumers. The CD-ROM has proved reliable and efficient, which is why it has remained relevant even as CD sales have declined in recent times.

The “compact disc-recordable” (CD-R) starts out blank and allows users to record over the empty data spiral, similar to the function of a floppy disk. This engraved information becomes a permanent etching on the disc, which can hold anywhere between 74 and 80 minutes of data.

Similarly, the “compact disc-rewritable” or CD-RW is a blank disc that allows the empty data

spiral to record information that can be erased and recorded over, as if the disc were still blank. Erasing and rerecording data is done with lasers that reach different temperatures and interact with the metal alloys within the disc.

“Digital versatile discs” (DVDs) are high-capacity discs developed in 1995 and cocreated by Philips, Sony, Toshiba, and Panasonic. These discs’ storage capacity is measured in gigabytes, ranging anywhere from 4 up to 18 gigabytes. Since they store more than a standard compact disc, DVDs are commonly used to store motion pictures, video games, and some computer programs. From the late 1990s through the 2000s, DVDs were integral to bringing higher-definition audio and visual media to households that were previously seen only in commercial locations such as movie theaters.

In 2006, a new type of DVD emerged: the Blu-ray disc. Developed by the Blu-ray Disc Association, it

can store up to 50 gigabytes of data and produce a clearer picture due to the shorter wavelength of the blue-violet ray that reads the disc. The Blu-ray disc format was intended to take over the DVD industry, but its reception was not overwhelming. It has struggled to maintain a strong presence in light of continued DVD production, streaming media services such as Netflix and Hulu, as well as increased costs associated with making and selling Blu-ray discs.

There have been innumerable benefits from the advent of digital discs not only for the electronics and entertainment industries, but for the public, because of the amount of information it can consume, create, and reproduce. However, looking forward, digital discs are falling in popularity compared to streaming data over Internet networks, which is convenient and efficient. Without a need for digital discs, which are susceptible to scratches, breakage, deterioration, and loss, the public has begun to favor the alternative method of accessing data via streaming or the “cloud,” the invisible online network that allows for downloading and uploading of multimedia material over Internet connections. This has led entertainment companies such as Spotify, iTunes, and YouTube to serve households and businesses everywhere with data that exceeds disc quality and without the limitations of retaining, using, and caring for physical discs.

Taylor Alexandra Boyett

See also CD-ROM; Floppy Disk; *Vol. 3, Sec. 3: Video Game; Video Streaming Services*

Further Reading

- Hendley, A. M. 1985. *Videodiscs, Compact Discs and Digital Optical Disk Systems: An Introduction to the Technologies and the Systems and Their Potential for Information Storage, Retrieval and Dissemination*. Hatfield, UK: Cimtech, the National Centre for Information Media & Technology, the Hatfield Polytechnic.
- Khurshudov, Andrei. 2001. *The Essential Guide to Computer Data Storage: From Floppy to DVD*. Upper Saddle River, NJ: Prentice Hall PTR.
- Purcell, Lee. 2000. *CD-R/DVD: Disc Recording Demystified*. New York: McGraw-Hill.

CD-ROM

A “compact disc read-only memory” (CD-ROM) is a digital disc containing binary data read by a low-powered laser. James T. Russell, an American physicist and inventor, originally created the concept of compact discs in the 1960s. The disc was later refined and manufactured by a joint operation between Sony and Philips in the 1980s. CD-ROMs replaced both long-playing (LP) records as well as 3.5-inch floppy disks because of their versatility and ability to carry nearly 500 times the amount of data than a floppy disk and therefore larger amounts of personal and commercial data such as music, graphics, and programs. At their inception, CD-ROMs were seen as revolutionary, and they eventually led the way to the advent of recordable, rewritable, and digital versatile discs (DVDs).

Over his lifetime, Russell patented more than 50 inventions, with close to 25 of those relating to CD-ROM technology. His initial inspiration for the CD-ROM came as he noted that the physical contact between vinyl LP records and their players caused deterioration over time. He invented a disc, and subsequently a device to play it, that eliminated the need for such contact. Russell’s prototype was a rudimentary disc containing data that could be read by spinning counterclockwise while suspended above a light beam, which was made possible by laser technology.

Unfortunately, Russell found his invention hard to market to other companies at the time. Two decades later, realizing the potential of such technology, Sony and Philips partnered on refining and improving the concept. Through a process of combining polycarbonate, aluminum, and film lacquer, the CD-ROM was born and revolutionized the way material was marketed, sold, and distributed. CD-ROMs proved beneficial to software, gaming, and entertainment industries alike because of their read-only capabilities and their portability.

CD-ROMs manufactured for commercial and personal use are created by using a master disc as a way to replicate data in a mass production setting. To create the first disc, a film coating is applied over a glass disc, and information is embedded into it via a laser.

This creates pits and “lands” in the glass, which creates the mother, or master, disc. A metal alloy is then poured over this surface to create the father, or stamper portion, of the master set. It is this stamper that is applied over layers of polycarbonate in replication machines to create CD-ROMs with the original master information embedded on them. After a reflective layer, protective layer, and optional label are applied over the polycarbonate, the CD-ROM discs are ready for distribution.

CD-ROMs are inserted into a computer via a caddy or directly into a dedicated slot for compact discs. Inside the computer or device, a single laser beam is focused at the rotating disc. The laser beam records and translates the landscape of the transition from pits to lands embedded on the disc in binary code, represented as ones and zeros. This information is then interpreted by the computer, which then produces the media found on the disc for the user to utilize.

CD-ROMs were favored over storage solutions such as vinyl records and floppy disks because of their ease of use, portability, storage capacity, and low cost associated with production and resale. Over time, the ever-growing technological advances and security implementations in digital media resulted in the decline of the use of CD-ROMs. CD-ROMs, just as other compact discs, are susceptible to breakage and the violation of copyright laws, and they suffer from limitations on the amount of data they can store. Also, because CD-ROMs are read-only, they are severely limited in the amount of use a consumer can get out of them.

While CD-ROMs were a mainstay for a few decades, they were slowly phased out in favor of alternatives, including DVDs and Blu-ray discs. Eventually, digital discs will be phased out completely due to the advent of streaming, which allows data to be transferred digitally via the Internet and became the preferred method for distributing and deciphering data by the early 2010s.

Taylor Alexandra Boyett

See also CD and DVD; *Vol. 3, Sec. 1: Lasers; Vol. 3, Sec. 3: Video Game*

Further Reading

“CD ROM: The New Papyrus.” 1987. *School Library Journal* 33: 31.

Microsoft CD-ROM Yearbook, 1989–1990. 1989. Redmond, WA: Microsoft Press.

Stan, Sorin. 1998. *The CD-ROM Drive: A Brief System Description.* Boston: Kluwer Academic.

Computer/Information Technology

Even though computing-type technology can be traced to ancient times, computer/information technology (CIT), the storage, manipulation, and transmission of information in digital form, truly got its start during World War II (1939–1945). Since that time, CIT has gone through several iterations. With each generation of CIT, humanity has benefited from new tools, but CIT has also produced some philosophical and ethical dilemmas. Although we can’t predict the future with certainty, some experts have voiced concern over certain aspects of CIT’s future evolution.

The abacus, a counting machine, was invented during the 4th century BCE. Later developments included a device to predict the motions of the solar system and a device to calculate numbers. Unlike these pre–Industrial Age devices, the machines from the first CIT generation (1939–1954) were heavy and huge, ran on vacuum tubes, and were powered by electricity. During the war, the U.S. military used “the Colossus” to decode German secret messages. In 1945, the Ballistics Research Laboratory (in Maryland) developed the Electronic Numerical Integrator and Computer (ENIAC) to assist in the preparation of U.S. artillery firing tables.

After the war, Remington Rand sold the Universal Automatic Computer (UNIVAC) to the U.S. Census Bureau. In 1952, an upgraded UNIVAC was used to calculate the winner of the presidential election. Second-generation computers (1954–1959) generated less heat, were smaller, and weighed less than their predecessors, because they used transistors rather than vacuum tubes. In 1957, International Business Machines (IBM) sold computer model 608, the first computer on the commercial market.

The use of integrated circuits characterized CIT's third generation (1959–1971). During the 1960s, the ability to draw, type, and edit on a computer screen rather than on paper was realized with Sketchpad (1962) and an early word-processing program (1968). In the 1960s, IBM produced SABRE, the first airline reservation tracking system, and the U.S. Department of Defense began working on ARPANET (the forerunner of the Internet). The microprocessor was the cornerstone of CIT's fourth generation (1971–2011).

In 1973, Xerox introduced Ethernet, the first environment that allowed computers to communicate with each other. During the 1970s, Apple developed the first personal-size computer. In 1980, Bill Gates's work with IBM resulted in the creation of Microsoft, which became the largest software company in the world. In 1987, Apple developed HyperCard (a predecessor of the graphical environment later used on the World Wide Web), which allowed for the use of hypertext. The World Wide Web appeared in 1991. The massive content on the Web necessitated the development of various Web browsers, including Mosaic (1993), Netscape (1994), and Internet Explorer (1996). The easy access to information at users' finger tips ushered in the information age.

As CIT increasingly permeated everyday life, it became indispensable in many areas, including business, medicine, education, government, and the military. Some negative physiological effects of the constant use of computer keyboards included repetitive stress injuries, carpal tunnel syndrome, tendonitis, and tennis elbow. In the digital environment where data was transmitted both wirelessly and through wires, data encryption and antivirus software became the two most common reactions to the chief modern CIT issue: cybersecurity. In this regard, cyber criminals (hackers) were notorious for breaking into certain "secured" computer systems, such as those protecting bank accounts and national defense systems.

CIT's effects on social life have been profound. CIT has served to enhance freedom of speech in nations that would otherwise restrict it. Universities and colleges have increasingly offered online courses, which has made education much more accessible. However, other effects of CIT have been less desirable. For example, sociologists have feared that at

home, many people would interact with their "smart" devices more than they did with other people.

By the 2000s, video gaming became popular on home systems that allowed players to interact with a wide circle of people online. The Internet provided access to so many communities that it was not difficult for people to find those that shared their interests. Although it has been much more convenient for people to attend virtual communities than real ones that are many miles away, philosophers have questioned whether extended exposure to online friends who agreed with them would make them less tolerant to people in the real world who disagreed with them. For some people, virtual online communities have functioned as substitutes for real social groups.

In the work environment, e-mails, text messages, and video conferences have reduced the need for workers to gather. Some philosophers have pointed out that, in the absence of available credible information, the massive amounts of readily available unregulated Internet content could misinform people. Furthermore, Internet information can serve as a lens through which people view the world and persuade them to take certain actions. In other words, the philosophical question became whether humans are in control of CIT or if CIT is in control of humans.

Since the beginning of humanity, people have been locked into the cycle of physical life. They are born, grow, reproduce, and then die. Those who have lived to old age endure a body that has become increasing feeble. In the light of these facts of the human experience, some people have longed to break the cycle through technology. The idea was to develop a process by which doctors could transfer the contents (memories, knowledge, and consciousness) of human brains to durable robot bodies. After the data transfer, humans could theoretically live forever. Although the not-yet-existent technological process seems desirable to some, most people cringe at the idea of abandoning their human bodies.

In truth, the future fifth evolution of CIT is unknown, but experts have predicted two major developments: enhanced virtual reality (VR) and advanced artificial intelligence (AI). VR, a computer-generated simulation of a three-dimensional image and/or environment, was introduced in the 1960s. Since that time,

CIT has evolved with the use of headsets and the ability of the wearer to interact (through sight and sound) with VR displays. Doctors and medical students have used VR to perform practice operations, and with the use of VR, pilots have gained many hours of valuable flight simulation experience. In a similar way, astronauts have conducted training exercises to practice for complex maneuvers during space missions.

Scientists have been working on developing AI software to perform tasks normally requiring human intelligence since the 1950s. In the 1990s, IBM introduced Deep Blue, a computer designed to play chess without human assistance. The “thinking” ability of Deep Blue exceeded that of all other chess computer games with the number of moves it could consider before making a calculated decision. In 1997, Deep Blue became the first chess computer to defeat a world-renowned human chess champion. However, some critics claimed that Deep Blue’s knowledge base was too narrowly focused on chess and, therefore fell short of authentic human intelligence.

In the early 2000s, IBM rolled out Watson, a computer capable of answering questions posed in natural language. In 2011, Watson competed against two former champions on the quiz show *Jeopardy!* Watson’s ability to quickly access specific information from 200 million pages of content earned it the first-place prize of \$1 million. Since this highly publicized display of a “thinking machine,” business leaders have employed Watson in an effort to run more efficient enterprises. In 2016, Watson was used to conduct weather forecasting. In 2017, the tax preparation company H&R Block used Watson to enhance its client experience.

Some scientists and CIT experts (including Stephen Hawking and Bill Gates) have voiced concerns about the possibly disastrous outcome of a human reliance on AI. Since CIT systems have the ability to evolve much faster than humans, these experts believe that AI can develop to a point where humans may lose control over their own creation. This group has argued that human-designed safeguards, although necessary, are merely temporary solutions, because computer superintelligence would eventually supersede human intelligence. Although these scenarios may sound more like science fiction than reality to many people, Gates and others do not understand the general lack of

concern. According to this alarming view, as CIT becomes engrained in many facets of human life (from the operation of traffic lights to the deployment of defense systems), the level of AI development may determine whether fifth-generation CIT continues to function as a human tool or becomes a threat.

Rolando Avila

See also Apple; Artificial Intelligence (AI); Gates, Bill; IBM Personal Computer; Internet; Microchip; Microsoft; Personal Computer (PC); *Vol. 3, Sec. 1: ENIAC and the “ENIAC Girls”*; Universal Automatic Computer (UNIVAC); *Vol. 3, Sec. 3: Facebook*; Google; Virtual Reality (VR); Wireless Communication

Further Reading

- Campbell-Kelly, Martin, William Aspray, Nathan Ensmenger, and Jeffrey Yost. 2014. *Computer: A History of the Information Machine*. Boulder, CO: Westview Press.
- Fox, Richard. 2013. *Information Technology: An Introduction for Today’s Digital World*. Boca Raton, FL: CRC Press.
- Hafner, Kate, and Matthew Lyon. 1996. *Where Wizards Stay Up Late: The Origins of the Internet*. New York: Simon & Schuster.

Cray, Seymour (1925–1996)

Considered the creator of supercomputers, Seymour R. Cray was born on September 28, 1925, in Chipewaga Falls, Wisconsin. As a high school student, Cray studied electrical engineering and in 1943, he joined the U.S. Army, serving in the capacity of a communications soldier. In the European theater of World War II, he participated in the Battle of the Bulge, among others, before being recruited to a unit serving in the Philippine Islands. After he returned from war, Cray used his GI Bill to attend the University of Minnesota, where he received a bachelor of science degree in electrical engineering in 1950, followed by a master’s degree in applied math in 1951.

Engineering Research Associates (ERA), based in St. Paul, Minnesota, hired Cray to help in its project

constructing cryptographic equipment for the U.S. Navy. There, Cray worked on a wide variety of computer technologies ranging from vacuum tubes and magnetic amplifiers to transistors while also designing his first supercomputer, the 1103—also known as Univac I, the first computer to use random access memory (RAM).

In 1957, Cray left ERA to join Control Data Corporation (CDC), where he served as acting director and later as senior vice president until 1972. At CDC, he built the fastest computer then in existence, the CDC 1604—the first fully transistorized commercial computer, which worked without vacuum tubes. His next invention, the CDC 6600, is considered the world's first supercomputer with a processing power of nine megaflops (Mflops)—1 million floating-point operations per second—and cooled by Freon, another first. In 1963, Cray built the CDC 7600, running at nearly four times the capacity of the last model, and in 1968, Cray designed the CDC 8600 using four processors that all shared one memory core.

When board members of the CDC decided to phase out development of large-scale scientific computers, Cray left to found his own company, Cray Research Inc., based in his hometown of Chippewa Falls, Wisconsin. There, in 1976, Cray developed the Cray-1 TM vector supercomputer, which introduced integrated circuits to replace transistors. The Cray-1 had a processing power capable of 170 Mflops. From 1972 to 1977, he served as director, chief executive officer, and the president of Cray. In October 1977, he relinquished the presidency of Cray Research but remained chief executive officer and chairman of the board.

Cray resigned as chief executive officer in 1980, and in 1981, Cray stepped down as chairman of the board. He wanted to devote all his time to the development of the Cray-2 TM project. The new innovation for the Cray-2 TM came in utilizing gallium arsenide processing chips. In 1985, Cray created the Cray-2 computer system by in turn creating the gigaflop, equivalent to 1,000 Mflops, a barrier no one had thought could be broken. Cray experimented with gallium arsenide as an ultrafast semiconductor material, but he returned to the use of silicon chips. He also

introduced the use of Fluorinert, an inert fluorocarbon liquid, as a coolant.

In 1989, Cray founded the Cray Computer Corporation, based in Colorado Springs, Colorado, to work on the Cray-4, but the company shut down in 1995 due to financial pressures. In early 1996, Cray started SRC Computers Inc., but he died a few months later, on October 5, 1996 at the age of 71, due to injuries suffered in an automobile accident.

For his work, Cray has been honored with the W. W. McDowell Award by the American Foundation of Information Processing Societies and the Harry H. Goode Memorial Award for his contributions to large-scale scientific computer design and the development of multiprocessing systems.

Rosanne Welch

See also Apple; Computer/Information Technology; IBM Personal Computer; *Vol. 3, Sec. 1*: Universal Automatic Computer (UNIVAC); *Vol. 3, Sec. 3*: Linux

Further Reading

Murray, Charles J. 1998. *The Supermen: The Story of Seymour Cray and the Technical Wizards Behind the Supercomputer*. New Jersey: Wiley, John & Sons.

Weil, David, ed. 2002. *Leaders of the Information Age*. New Jersey: H. W. Wilson.

Dell, Michael “Saul” (1965–)

Founder of Dell Inc., manufacturers of the Dell computer, Michael “Saul” Dell was born to working parents Alexander, an orthodontist, and Lorraine, a stockbroker, on February 23, 1965. At a young age, Dell’s mother influenced him toward a career in business with frequent topics raised during dinner. He took to it quickly. At the age of 12, Dell displayed a natural affinity for business by buying and reselling postage stamp collections, netting himself a profit of \$2,000.

At the age of 15, Dell developed an interest in technology, in particular in personal computers. He convinced his parents to allow him to buy the new Apple II personal computer with money from his savings. On

the same day that he bought the brand-new machine, Dell dismantled the computer in an attempt to understand its inner workings. This was the start of what would become a lifelong obsession with technology and computers. Throughout the rest of his teenage years, Dell continued to immerse himself in the culture of computers, from learning enough to be able to help fix his friends' computers to skipping school to attend the annual National Computer Conference.

In 1983, Michael Dell started his first year of college at the University of Texas. Though his parents had hoped he would study to become a physician, Dell had other plans. While in school, Dell continued to help people fix and upgrade their computers for a profit. Dell decided to drop out of college and register Dell Incorporated as an official business. He never returned to the University of Texas.

By 1984, after its first full year of business, Dell Incorporated earned over \$6 million in sales. One of the biggest ways that Dell Inc. stood out from the competition was the company's philosophy of selling computers directly to customers via mail rather than through a middleman's storefront. This required supply chain innovations and a promise of solid customer service, since there would be no in-store counter to go to for questions or repairs. In a variety of interviews, Dell explained that often, while he was on the Internet, he scanned forums for user opinions of his company and its products, and he used that feedback to further improve the company.

Five years later, in 1989, he and Susan Lynn Lieberman married. They would have four children. In 1992, Dell became the youngest CEO of a Fortune 500 company. Throughout all this growth, Dell also created a track record of being very philanthropic. In 1999, he and Susan established the Michael and Susan Dell Foundation, a private charity that has provided aid to people in need, such as victims in Southeast Asia of the 2004 Indian Ocean earthquake and tsunami. The charity has also donated to Dell's former university, the University of Texas.

By 2000, after 17 years of business, Dell was a billionaire, and Dell Incorporated was one of the models of success in the business of computer sales. After 30 years in business, the company is still thriving. In

2016, Dell expanded his interest in technology companies by acquiring the enterprise software and storage company EMC Corporation.

Dell Incorporated has proven Michael Dell to be one of the biggest pioneers in forming the technology landscape of today. With the philosophy that technology is about enabling human potential, Dell has been instrumental in ushering in the age of information technology and personal computers.

Michael Yu

See also Apple; IBM Personal Computer; Personal Computer (PC)

Further Reading

- Dell, Michael, and Catherine Fredman. 2000. *Direct from Dell: Strategies That Revolutionized an Industry*. New York: Harper Business.
- Fishman, C. 2012. "Face Time with Michael Dell." <https://www.fastcompany.com/42202/face-time-michael-dell>, accessed August 31, 2018.
- Graduate School of Business, Stanford University. 2000. *Dell Direct*. Stanford, CA: Graduate School of Business, Stanford University.
- Magretta, Joan. 1998. *The Power of Virtual Integration: An Interview with Dell Computer's Michael Dell*. Boston: Harvard Business Review.

Digital Photography

Digital photography is a type of photography that uses arrays of electronic photodetectors to capture images instead of photographic film and then stores the images as a computer file instead of as negatives or in print. In 1975, Steven Sasson, an engineer at the Kodak company, helped invent digital photography.

The first prototype of the digital camera was made up of Motorola parts with a Kodak movie camera lens. Then, connected to the bottom of the camera was a half dozen circuit boards wired together. The inside of the camera was more complex. To create digital photography, Sasson had to find a way to save the captured image and view it afterward. He decided to use a cassette tape to capture an image, but he needed to figure out how to store the image on it. He solved this

by using digitalization, a process that turns electronic impulses into numbers.

Using this process, he then stored the images in random access memory (RAM) and then on the cassette tape. The cassette tape would be taken out of the camera and placed into a computer so the image could be viewed. This camera took 50 milliseconds to capture an image and then an additional 23 seconds to save it on the cassette tape. The images were in black and white only until digital photography slowly advanced. Now, it is more convenient and easier to capture an image with digital photography than it was in 1975.

Other camera companies developed their own digital cameras. In 1991, Nikon sold the first digital camera. It did not look anything like the Kodak camera and was mainly used for photojournalism. Then in 1995, Apple came out with the Quick Take 100, which was more affordable. Its photographs could be viewed by using a serial cable connected to a computer.

1995 became the year for consumer digital cameras. Companies making them included Casio, Kodak, and Sony. Now we can do digital photography with cell phones and more advanced digital cameras. We can take pictures at any place and at any time. Digital cameras now vary in size depending on intended use. Some are simple, and some are for professional use. Now there are digital cameras the size of the cassette tape that was first used to store digital images.

Digital photography has changed photography exponentially. Consumers can take as many photographs as they want, limited only on the amount of storage space a camera or memory card has, not the number of exposures allotted per roll of film. We can also view images immediately upon taking them. If an image is blurry or otherwise unsatisfactory, it can be deleted instantly. With continually updated software, we can modify any photograph. There are options to change the exposure of the image, do color correction, or change the image from color to black and white. With the advances in digital photography, there are countless possibilities for manipulating images.

When digital photography first appeared, many camera companies argued that film should not be abandoned. But the use of film began a slow decline. Even though both methods are still used to capture images, they are different in many ways. One difference is in the resolution. Digital photography has high resolution because of software capabilities. A camera has digital image sensors that can be programmed for certain resolutions by counting the number of pixels within the parameters of the image. Film does not have pixels; it uses angular resolution.

With film cameras, the type of camera and film determines the size of a picture. There are different types of film and different camera formats as well. In digital photography, how you view the image can affect the size of a picture. Viewed on the camera, it is the size at which the image was taken, but if it is uploaded to a computer, there is an option to enlarge it or make it smaller. The range at which a photograph is taken can have an effect on the image as well. And with film, once a photograph is taken, it cannot be undone.

One important difference between digital and film photography is in cost and convenience. While this depends on what type of camera is used (and the cost of memory cards and film can vary), film is generally more expensive than digital memory. And, once the storage on the card is full, images can be transferred to a computer or other storage and deleted from the card. The card can then be reused. Film can only be used once, and images on it can eventually fade.

Marissa A. Guerrero

See also Vol. 2, Sec. 1: Eastman, George; Photographic Film; Roll Film

Further Reading

- McKay, B. D. 2013. "The Use of Digital Photography in Systematics." *Biological Journal of the Linnean Society* 110, no. 1: 1–13.
- Van House, N. A. 2011. "Personal Photography, Digital Technologies and the Uses of the Visual." *Visual Studies* 26, no. 2: 125–34.
- Zahra, A. 2008. "Limitless Images: Digital Photography in the Classroom." *Delta Kappa Gamma Bulletin* 75, no. 1.

Primary Document: Excerpt from the Patent for Kodak's Digital Camera (1978)

In December 1978, Kodak issued a patent for the first digital camera, the electronic still camera. It was invented by Steve Sasson, one of its scientists. To store the digital photograph, Sasson used digitalization. He turned the electronic impulses into numbers and stored them in RAM memory. Afterward, the image could be viewed on a screen. This excerpt from the patent provides details of how the camera captured digital photographs and was hooked up to a screen to display them. It discusses the structure of the camera and the use of digital photography.

Description of the Prior Art

Conventional cameras employ a shutter for exposing for a limited duration photographic film located at a film exposure plane. Film processing solutions are required to produce a visible image of the photographed scene. As is well known, processed photographic film may not be reused.

Recently, considerable effort has been given to the development of solid-state elements for imaging purposes. Such elements offer an advantage over photographic film in that, theoretically, they can be reused any number of times for imaging.

A solid-state imaging element of the type known as a charge transfer device can include a semiconductive substrate doped with majority carriers and covered with a thin insulating film upon which is located an array of electrically conductive electrodes. A depletion region or potential well is formed within the semiconductor under electrodes biased by a voltage of the proper polarity. The use of a charge transfer device involves the basic concept of forming a charge pattern consisting of packets of minority carriers in the potential wells. In the course of an

optical imaging process, photons incident upon the semiconductor generate minority carriers within these potential wells in proportion to the amount of light impinging upon the semiconductor in the near vicinity of each well. These packets can be transferred through the semiconductor by sequentially biasing the electrodes. The potential wells effectively “move” through the semiconductor sweeping the minority carriers along within the wells. At an appropriate location these packets may be detected, for example, by removing them sequentially from the semiconductor by means of a reverse-biased diode coupled to transfer electrodes. An arrangement for read-out of information from a charge transfer device is disclosed in IEEE Transactions On Electron Devices, Vol. ED-20, No. 6, June 1973, in an article entitled “interlacing In Charge Coupled Imaging Devices,” by Carlo H. Sequin.

As with conventional photographic film, to obtain a scene image having a proper contrast, the imaging element must not be overexposed, or, in other words, the potential wells must not be saturated with minority carriers during the exposure interval. However, even in the absence of illumination, the regions constituting the potential wells tend to saturate with the passage of time by means of the thermal generation of minority carriers. Carriers generated in this manner constitute an unwanted signal commonly known as a “dark current.” It is important that this signal be only a small fraction of the signal produced by incident illumination, particularly if the dark current is nonuniform over the imaging area.

Source: United States Patent Office. Patent US4131919A. Serial No. 4,131,919. December 26, 1978.

DVD. See CD and DVD

Elion, Gertrude (1918–1999)

Together with fellow scientist George Hitchings, the American pharmacologist and biochemist Gertrude B. Elion revolutionized the field of pharmaceuticals and medicine by developing a systematic method to

manufacture drugs. Her innovations included the production of the first medications used to treat leukemia and the first immune-suppressive agent used during organ transplantation, as well as other drugs to treat malaria, gout, toxoplasmosis, and many viruses. She won a Nobel Prize for medicine in 1988.

Gertrude Belle Elion was born in New York City on January 23, 1918. Her parents were Lithuanian



Biochemist Gertrude Elion and coworker George Hitchings were awarded the Nobel Prize in Physiology or Medicine in 1988. Their work in developing drugs to treat leukemia and AIDS helped millions of those afflicted to live fuller lives. (Bettmann/Getty Images)

and Polish immigrants who lost much of their wealth during the Wall Street crash of 1929. After graduating from high school at age 15, she only had few educational choices due to her family's poor economic conditions. She was accepted at the women's Hunter College in New York, where she obtained her BS in chemistry when she was just 19 years old. She earned her MSc degree at New York University four years later, in 1941. At NYU, Elion struggled with financial hardship, and afterward, gender bias prevented her from finding a stable job as a chemist. She worked as a biochemistry teacher at New York Hospital School of Nursing, a food quality supervisor at A&P supermarkets, and a research chemist at Johnson & Johnson.

In 1944, Elion was hired at Burroughs Wellcome Laboratories (today known as GlaxoSmithKline) in Tuckahoe, New York, as an assistant to Dr. George Hitchings, who gave her progressively more responsibility. The two discovered a new way to design compounds by exploiting the biochemical differences between human cells and pathogens to block the spreading of infections. They also found a new method to selectively force cancer cells into incorporating artificial substances that stopped their growth without affecting healthy cells. Hitchings and Elion formulated a plethora of new substances that have saved millions of lives by providing new, effective treatments for viruses, urinary tract infections, malaria, gout, leukemia, and meningitis. Their formulas also help during organ transplants.

Elion's work focused almost entirely on the purines, a group of organic compounds found in organ meats, vegetables, and seafood. Any substance that interacts with the pathways that control purine production and breakdown may severely damage a cell's DNA sequences, causing its death. Thanks to recent breakthroughs in biochemistry that elucidated those pathways, in the mid-1950s, Elion and Hitchings developed the first two drugs for the treatment of acute leukemia: mercaptopurine (also known as Purinethol or 6-MP) and thioguanine.

Together with Roland K. Robins and Wayne Rundles, she also found that allopurinol, a compound originally synthesized as a potential antineoplastic agent, was indeed effective to treat gout. In 1963, she developed azathioprine, the first immunosuppressive agent that could block the production of antibodies. Together with glucocorticoids, azathioprine was the standard treatment to suppress the immune system's rejection of foreign tissues during heart and kidney transplants for the next two decades.

She also developed the antimalaria agent pyrimethamine, the chemotherapy agent nelarabine, and the antibiotic trimethoprim. In 1967, Elion was appointed head of the Department of Experimental Therapy, which contained several different sections that coordinated their efforts to develop new drugs, including immunology, virology, chemistry, pharmacology. It also had a tissue culture laboratory, where Elion developed the world's first antiviral drug—acyclovir—

which is still used today to treat herpes, shingles, and chicken pox.

Elion was also adjunct professor of pharmacology and of experimental medicine at Duke University from 1971 until her retirement. Although she officially retired in 1983, Elion kept serving as an advisor for the World Health Organization and became president of the American Association for Cancer Research. She also actively contributed to the development of azidothymidine (AZT), the first drug approved for the treatment of AIDS. Still holding the title of scientist emeritus, Elion was awarded the Nobel Prize in Medicine in 1988 together with Sir James Black and her colleague George Hitchings.

Later in life, she was presented with additional awards, such as the National Medal of Science that she received from President George H. W. Bush in 1991. During the same year, she was also the first woman to be inducted into the National Inventors Hall of Fame, and in 1995, she was elected a foreign member of the Royal Society. Over the course of her career, she received 23 honorary degrees and held a total of 45 patents in medicine. Elion died at the age of 81 on February 21, 1999, in Chapel Hill, North Carolina.

Claudio Butticè

See also AIDS Research; Artificial Heart; *Vol. 2, Sec. 3*: Clarke, Edith; Thomas, Vivien Theodore

Further Reading

Frängsmyr, Tore, ed. 1989. *Les Prix Nobel. The Nobel Prizes 1988*. Stockholm: The Nobel Foundation.

Wasserman, Elga R. 2000. *The Door in the Dream: Conversations with Eminent Women in Science*. Washington, D.C.: Joseph Henry Press.

Floppy Disk

The first memory disk was created at IBM and introduced to the public in 1971. Invented by IBM engineers led by Alan Shugart, floppy disks were a significant advancement in the way information could be accessed, stored, and distributed. The nickname “floppy disk” was due to the flexible materials these disks were composed of. Coated with magnetic iron

oxide, the earliest version featured an eight-inch plastic disk. The floppy was designed for loading microcodes into the controller of the IBM 3330. The Merlin disk pack file could store 100 megabytes of data. Due to advancements in hardware, the floppy disk later became known as the “diskette” and became a slimmer, 5.25-inch disk that was used in IBM’s first personal computer in 1981.

The 5.25-inch diskette was developed in 1976 by Alan Shugart of Wang Laboratories. An Wang of Wang Laboratories wanted to redesign the floppy so it could be used with its desktop computers. The slimmer size was decided on by engineers Jim Adkisson, Don Massaro, and An Wang at a bar when Wang used a drink napkin to show he wanted the disk to be “about that size”—which turned out to be 5.25 inches wide. The capacity of information storage during this time was measured in kilobytes as compared to the larger formats of modern portable drives measured in gigabytes. By 1978, more than 10 manufacturers were producing 5.25-inch floppy drives that were capable of storing approximately 1.2 MB of data.

There were more improvements over the years. Sony introduced a 3.5-inch version of the floppy drives and diskettes in 1981. Made with hard plastic cases, they weren’t flexible but continued to be called floppy disks. These diskettes evolved from storing 400 KB of data to 720 KB (“double density”), and finally, they had a 1.44 MB, “high-density” storage capacity. With improvements in design, storage capacity, and style, the new floppy disk gained more popularity and recognition, and the 5.25-inch version had a significant plunge in sales. This old version’s recording surface was easily damaged by fingerprints where there was open access to it, and without a hard case, it was easily bent.

Composed of a drive motor, stepper motor, read/write heads, circuit board, and a mechanical frame, the diskette has relies on its hardware to work properly. The floppy disk functions similarly to a cassette tape, as they are both composed with iron oxide, a ferromagnetic material. The floppy is also similar to recording tapes because it is a circle of magnetic material grabbed by its center and spun like a record inside its housing. Much like the head on a tape deck, the read/write head contacts the recording

surface through an opening in the plastic covering, or shell.

From the late 1970s through the 1990s, floppy disks were recognized as an almost universal data format whose primary function was to store data, but it became a file transfer system. The floppy offered an inexpensive and reusable way to store information with the option of deleting files, and it became an iconic part of the technological evolution. Notable forms of the floppy disk include the original 8-inch disk, the 5.25-inch minifloppy, the “Twiggy” disk, the 3-inch compact floppy disk, Mitsumi’s “Quick Disk” 3-inch floppies, and Sony’s 3.5-inch disk.

For almost 40 years, the floppy disk ruled the market as an essential way to transfer data or files, but the introduction of new formats such as CDs, USB drives, and other forms of high-speed computer networking and cloud storage in the mid-1990s led to a decline in their popularity. With a modern design and improved storage capacity, the USB “thumb drive” led to the gradual disappearance of the floppy drive. The decline in floppy disk usage became more apparent as computer companies began releasing floppyless computers. A notable example was in 1998, when Apple released the iMac. It didn’t have a slot for floppy disks at all. After the year 2000, floppy disks had almost completely disappeared. Increasingly rare, they are only used with older systems or with legacy industrial computer equipment.

Peg A. Lamphier

See also IBM Personal Computer

Further Reading

Marshall, Stephen J. 2017. *The Story of the Computer: A Technical and Business History*. CreateSpace Independent.

Fossey, Dian (1932–1985)

Dian Fossey was one of the first American primatologists to study gorillas. She was one of the trio of women called the “Trimates” (the other two are Jane Goodall and Biruté Galdikas). Fossey lived with and studied gorillas in their natural habitats. Later, her

goals shifted from research to conservation, because gorilla populations were rapidly declining due to poaching. Her efforts became controversial after she allegedly tortured poachers. In 1985, she was found murdered at her research station.

Fossey was born on January 16, 1932, in San Francisco, California. Her parents divorced when she was six, and her mother was remarried to Richard Price. The Prices hardly ever acknowledged Fossey and oftentimes made her eat dinner alone. She took equestrian lessons and dreamed of becoming a veterinarian, applying for the veterinary program at the University of California, Davis. After failing chemistry and physics courses, Fossey enrolled in the occupational therapy program at San Jose State. Once she graduated in 1954, she moved to Louisville, Kentucky, and worked with polio-stricken children and tuberculosis patients.

In 1963, Fossey took a loan to travel to Africa, where she toured Tanzania and encountered Louis Leakey, the famous anthropologist who studied human origins. Together, they discussed the importance of studying nonhuman primates. She then traveled to Zaire (now the Democratic Republic of the Congo) and met Joan and Alan Root, who were filming a wildlife documentary about mountain gorillas. The Roots invited her to join them. After seeing gorillas for the first time, Fossey was in awe of and felt connected to gorillas.

When she returned home, Fossey wrote about her adventures and published photos in the local paper. In 1966, she met with Leakey again in Louisville. Leakey wanted a protégé to help him research gorillas. Fossey volunteered to study the gorillas, but Leakey told her that she needed to have her appendix removed first. Six weeks later, he wrote to say that he was testing her determination and did not actually require an appendectomy. But Fossey had already had the procedure done. She left for Africa soon after.

Fossey spent 18 years living with and studying the primates in the mountain forests of Rwanda. Fossey built her first research station in the Virunga Mountains of Zaire. Six months later, a civil war broke out, and rebels forced her out of the country. This was a blow, as the gorillas had become familiar to human researchers and photographers. When she relocated to

the other side of the mountains in Rwanda, the gorillas she studied had only met humans as poachers. Her new research station, called Karisoke, became her home for the next two decades.

Fossey earned the gorillas' trust by watching them where they could clearly see her. She learned to imitate their calls and hoots. The younger gorillas would play with her notebooks and pencils while the adults kept guard around her. Fossey recorded everything she saw. She published her research notes in several science journals. With her research and writing, Fossey educated the world about gorillas and how they were gentle giants with complex social behaviors and hierarchies. This culminated in her book *Gorillas in the Mist*, which was later made into a movie.

Over time, Fossey's focus shifted from research to conservation. In the first four months in Rwanda, her research team found 900 hunting traps. Poachers targeted gorillas for the hands and heads of adults, which were to be made into souvenirs and trophies, and they also targeted live babies, who were sent to zoos and individuals around the world. In 1978, one of Fossey's gorilla families was massacred. She buried their bodies next to her research station, and her conservation goals took a dark turn.

Fossey began using extreme techniques to stop poachers. While her writings kept some tourists from buying souvenirs made from gorillas, Fossey terrorized the poachers to keep them out of the mountains. The Rwandans claimed that she taught the gorillas to fear dark-skinned people over whites, kidnapped the child of a poacher who had captured a baby gorilla, and whipped poachers she arrested with stinging nettles.

Fossey's opposition to poachers and tourists eventually led to her murder. On December 27, 1985, she was found dead in her ransacked cabin. The investigation was poorly handled and remains unsolved. Fossey was laid to rest in Karisoke's graveyard, right next to her gorillas. In 1981 the Rwanda gorilla population was under 250 individuals. Today, there are almost 500 gorillas in the Virunga Mountains. Without her research and constant protection, they would most certainly be extinct.

Elliott Popel

See also *Vol. 3, Sec. 1*: Carson, Rachel; Goeppert-Mayer, Maria

Further Reading

Montgomery, Sy. 2009. *Walking with the Great Apes*. New York: Chelsea Green.

Gates, Bill (1955–)

With the help of Paul Allen (1953–), a longtime friend, William Henry Gates III cofounded Microsoft, a company responsible for developing user-friendly software that revolutionized the computer industry by making it possible for people without technological training to use computers at work and at home.

Gates, who was greatly influenced by his parents, was a gifted student, software designer, and businessman. The success of his company was tied to several factors, including his work ethic, marketing and innovation ability, and strategy. After marrying in 1994 and blocking an antitrust lawsuit against his company in 1998, he retired and devoted his time and fortune to philanthropic endeavors aimed at improving education and eradicating diseases under the banner of the Bill & Melinda Gates Foundation. His philanthropic role was made possible by his work in technology. His optimistic view of the role that technology could play to improve lives has been unshakeable. Gates has received many awards and recognitions for his work.

Gates was born in Seattle, Washington, on October 28, 1955. His father was a successful lawyer, and his mother was a schoolteacher who served as chairperson of United Way International, an organization dedicated to supporting education and health initiatives. Gates developed an interest in computer science in seventh grade at Lakeside School, a private school in Seattle. That year, he met Allen, who shared his interest in computers. While the two teenagers were still in high school, in 1972 they established Traf-On-Data, a temporary firm that used software to determine local traffic patterns. In about a year, the small business had earned them \$20,000. As part of his college application, Gates scored a perfect 800 on the mathematics section of the Standard Aptitude Test (SAT). Although he had developed an interest in computers at

an early age, he chose to study law (like his father) when he enrolled at Harvard in 1973.

At Harvard, Gates accumulated a small fortune as a poker player. Years later, Gates boasted that his success in poker had a lot to do with his ability to calculate mathematical odds. In 1975, Allen dropped out of Washington State University and asked Gates to drop out of Harvard so that they could go into the computer software business together. Gates was convinced after Allen showed him a story in *Popular Mechanics* magazine about the Altair 8800, a \$350 million micro-computer developed in New Mexico by Micro Instrumentation and Telemetry Systems (MITS).

The partners established Microsoft in 1975. Gates paid part of the start-up costs with his poker winnings. Research and development were constant at Microsoft. For about two decades, Gates put in more than 12 hours of work every day of the week (including weekends). It was not until 1994, after he married Melinda French, that he adopted a lighter work week (of a maximum of 12 hours a day during the week and 8 hours a day on weekends).

From 1975 to 1980, Microsoft had moderate success by developing programs for Commodore and Apple business computers. A major focus of the company was the development of Beginner's All-Purpose Symbolic Instruction Code (BASIC), an early programming language. In 1980, Microsoft got its first big break when International Business Machines (IBM) asked Gates for help with its attempt to develop a better personal computer (PC). In response, Gates created the Microsoft Disk Operating System (MS-DOS), which used a text command line interface.

By 1984, MS-DOS had sold more than 2 million copies, making it the world's leading operating system. By the end of the decade, it had sold more than 100 million copies. In 1987, Gates unveiled Windows, which used both a text and a graphic (icon) user interface. He followed it up with the Microsoft Network (MSN) in 1994, Windows 95 in 1995, and Windows 98 in 1998. Windows 98 sold more than half a million copies in the first three days after its release. By 1998, Gates had become the world's wealthiest self-made man.

Marketing played a major part in Microsoft's tremendous success in the 1990s. Microsoft was able to

ensure a steady income stream with advertising that informed consumers of the improved features and greater functionality of each new computer system. Therefore, even though many people had computers, they kept buying newer ones. Another major factor that contributed to Microsoft's success was constant innovation in computer software. For example, in 1997, Microsoft entered the multimedia market with CD-ROMs. Within a couple of years, CD-ROMS with various programs (including games) flooded the market. To promote future sales of CD-ROMS, Microsoft designed them with exclusive compatibility to certain operating systems. Therefore, when consumers purchased newer computers with the latest operating systems, older CD-ROMS became obsolete.

Another reason for Microsoft's success had to do with strategy. Since most computers were equipped with a Microsoft operating system, Gates bundled Microsoft software packages (including word-processing and spreadsheet software) on computer desktops. In an attempt to corner the new Internet market, Gates also bundled each Windows 95 and 98 computer desktop with Microsoft Web browsers. He made Internet access deals with America Online (AOL), Intel, TCI Broadband, Time Warner, and Road Runner.

Many competitors complained that Microsoft had gained a monopoly in the computer and Internet businesses. In 1995, the U.S. Department of Justice blocked Microsoft's attempt to purchase Intuit (a personal finance software company). In 1998, the Department of Justice (along with 18 state attorney generals) filed an antitrust lawsuit against Microsoft. In 1999, a judge for the U.S. States District Court of Columbia, Thomas Penfield Jackson, ruled that Microsoft was, in fact, a monopoly. The ruling made it possible for a multitude of competitors to sue Microsoft for damages. It even made it possible for the U.S. government to break up Microsoft into smaller, less dominant companies. However, the power of the ruling soon eroded, because Jackson's comments to the press (calling Gates an unethical businessman) cast doubt on the judge's impartiality. The U.S. Court of Appeals upheld that Microsoft was a monopoly by a unanimous vote, but it ruled that a new judge would have to decide Microsoft's penalty. However, Microsoft lawyers were able to block a penalty from being issued by

offering to settle the case instead. After two years of negotiations, Microsoft lawyers struck a deal with the Justice Department. The 2001 settlement did little to change Microsoft's great influence in the computer and Internet industries.

In 2000, Gates remained on as Microsoft's chairman, but he stepped down as CEO. He vowed to give away 95 percent of his wealth to charity. Through the Bill & Melinda Gates Foundation, he chose (like his mother) to focus on ways to improve education and combat world diseases. In the field of education, the foundation was committed to donating billions of dollars to support initiatives in public schools and colleges. Two of its greatest areas of focus were helping poor minority groups and improving teacher training, even though skeptics questioned the power of money to save schools. In 2003 alone, the foundation donated more than \$35 million to the Program for Appropriate Technology in Health (PATH) to fight encephalitis. By 2010, the foundation had donated more than \$13 billion in global health grants. However, some critics charged that the foundation lacked a satisfactory way to gauge the effectiveness of its donations. Other critics contested the way that its health grants were awarded. For example, in 2010, a team of researchers at University College London reported that the foundation's donation trends lacked a transparent peer review process. In spite of the criticisms, Gates remained optimistic. He was aware of how computer and Internet technologies could be used to enhance education. He was also aware that technological breakthroughs had the potential to improve world health. In short, Gates possessed a faith in the power of technological innovation to help humanity overcome problems, including illiteracy, poverty, and disease.

Gates wrote two books: *The Road Ahead* (1995), which summarized the implications of the PC and the Internet on the present and the future, and *Business & the Speed of Thought* (1999), which described the modern reality of the integration of business and technology. Gates has been the subject of several documentaries, including the television miniseries *The Machine That Changed the World* (1990). His story has also been told in feature films including *Pirates of Silicon Valley* (1999) and *Steve Jobs vs. Bill Gates: The Competition to Control the Personal Computer*,

1974–1999 (2015). He has been the recipient of many awards, including the U.S. National Medal of Technology (1993) and New York's Institute of Technology's President's Medal of Leadership Award (1995). In 2004, he was given the rare honor for an American of being named Knight Commander of the Order of the British Empire for his service to technology. *Time* magazine named Gates one of the most influential people of the 20th century.

Rolando Avila

See also CD and DVD; Computer/Information Technology; Jobs, Steve; Microsoft; *Vol. 3, Sec. 3*: Linux

Further Reading

- Gates, Bill. 1996. *The Road Ahead*. New York: Penguin.
- Gates, Bill. 1999. *Business @ The Speed of Thought: Using a Digital Nervous System*. New York: Warner Books.
- Lowe, Janet. 1998. *Bill Gates Speaks: Insight from the World's Greatest Entrepreneur*. New York: John Wiley & Sons.

Genetic Engineering

Humans have been altering the genetics of organisms for over 30,000 years by domesticating animals and plants through selective breeding. In the past few decades, the direct DNA alteration of an organism's genome using modern biotechnology has had many useful applications in agriculture, medicine, and scientific research. Scientists have genetically engineered bacteria to synthesize human insulin, among other medical and technological breakthroughs. The most popular controversial application of genetic engineering among the public is, perhaps, the manipulation of food production. Genetically modified organisms (GMOs) and genetically modified (GM) foods have many beneficial possibilities, but they also raise some concerns.

The principle on which genetic engineering is founded is that genetic information, encoded by DNA and arranged in the form of genes, is a resource that can be controlled in several ways to achieve goals in

both pure and applied science and medicine. The term “selective breeding,” coined by Charles Darwin (1809–1882), is the process of selecting organisms with the most desirable or advantageous traits and mating them with the aim of furthering these traits in their offspring. Early humans had no concept of genetics; however, they were still able to cause significant genetic changes to a species by repeatedly choosing selected traits. For example, wild wolves in East Asia were domesticated and selected to increase obedience. Over thousands of years, descendants of these wild wolves were selected for their body shape, temperament, behavior, size, hair length, and color, giving us what we know today as the dog. There are hundreds of dog breeds recognized by the World Canine Organization, yet they all belong to the same species: *Canis lupus familiaris*. Whereas natural selection occurs naturally, selective breeding is referred to as “artificial selection” due to human intervention.

Ten thousand years ago, corn did not exist; there was only teosinte—several wild species native to Mesoamerica. Teosinte was artificially selected by ancient Mesoamericans and is the major component of what evolved to become corn, or maize. The ancient Sumerians and Egyptians used yeast to brew wine and to bake bread as early as 4000 BC. Many ancient civilizations exploited tiny organisms that live in the earth by rotating crops in the field to increase crop yields. People in Mesopotamia used bacteria to convert wine into vinegar. The Greeks used crop rotation to maximize crop yield and also practiced various methods of food preservation such as drying, smoking, curing, salting, etc. All these techniques and processes were practiced in the Middle East and South East Asia, including ancient India.

Biotechnology, according to the U.S. National Science Academy, is the “controlled use of biological agents like cells or cellular components for beneficial use.” Before the 21st century, the term “biotechnology” referred to traditional activities such as making dairy products, wine, bread, beer, etc. For example, the fermentation done in food preparation, by which living organisms such as bacteria or yeast are employed to make useful products, can be considered “classical biotechnology.” Modern biotechnology is similar to

classical biotechnology but differs in technique. The technological advancements of the 20th century in the fields of chemistry, biology, physics, engineering, information technology, and computer application have resulted in modern biotechnology.

In 1906, biotechnology took a leap forward when Gregor Johann Mendel, a part-time schoolteacher and Augustinian monk, announced the findings of his experiments. Using statistical methods in biology for the first time, Mendel established the laws of heredity. He predicted the existence of genes that only recombined and did not change their identity from one generation to another. Derived from the term “genesis,” which relates to the beginnings of things, the science of genetics seeks to understand how organizations both differ from and resemble their parents. Every gene is thought to correspond directly to a specific trait.

By the 1920s, the study of genetics was instrumental in assisting plant breeders to develop improved crops. By the 1940s, agriculture had been transformed by genetics, and the Green Revolution of the 1960s was thus made possible. The discovery of DNA, the material that stores hereditary information in cells, revolutionized the science of genetics. Friedrich Miescher had discovered the chemical DNA in 1869, but it was not accepted as the chemical basis of genes until the early 1950s. In 1953, Rosalind Franklin, Francis Crick, and James Watson discovered the double-helix structure of DNA: two strands were twisted around each other like spiral staircases with bars instead of steps. The structure, function, and composition of DNA are virtually identical in all living organisms. The precise ordering of the chemical base in the DNA molecule is what makes each creature unique. This gave scientists the idea of changing the ordering of chemical bases and so to modify life-forms. H. Gobind Khorana and Marshall Nirenberg carried out the deciphering of the genetic code in 1961.

Between 1972 and 1973, U.S. biochemists Stanley Cohen and Herbert Boyer developed a technique that allowed pieces of DNA to be cut in specific places and attached to the DNA of a target organism. They were the first to directly transfer DNA from one organism to another. The possibility of inserting a human gene into a bacteria and mass-producing the gene led

to the biotechnology revolution. In 1975, the Asilomar Conference on Recombinant DNA was where the first safety regulations for biotechnology were laid out. In 1976, Herbert Boyer formed the first genetic engineering company, Gentech, with the aim of genetically modifying bacteria to produce human insulin. In 1978, Hamilton Smith, Daniel Nathans, and Werner Arber were awarded for discovering enzymes that act like biological scissors, an important tool used in modern genetic engineering.

The 1980s marked the discovery of DNA fingerprinting, a genetically engineered vaccine for hepatitis B, the creation of GM foods, and the rise of the anti-biotechnology movement. Jeremy Rifkin was an anti-biotechnology activist who was against the awarding of the first patent for genetically modified bacteria to Boyer and Cohen. In 1983, Stephen Lindow received the approval to release the first GM bacteria into the environment. In 1988, the entire human genome was planned to be mapped, which was eventually completed in 2000.

Genetic engineering requires a scientist to perform the successful completion of a series of five steps using modern biotechnology. Scientists must first extract the DNA of a desired organism. For instance, if the goal is to improve the nutrition of rice to include more vitamin A, then a gene is added to increase biosynthesis of beta-carotene, a precursor of vitamin A. The second step of genetic engineering involves gene cloning, which is done to separate the gene of interest from other genes, to make thousands copies of the gene of interest, and to transfer it to the target organism.

Copies of genes are made by polymerase chain reaction (PCR), a technique that revolutionized genetic engineering in 1985. When a gene has been cloned, scientists design the gene to function inside a different organism by cutting the gene apart with enzymes and by replacing the sticky ends that have been separated. The gene of interest is inserted into plasmids, tiny circles of bacterial DNA. Using the plasmids carrying the gene of interest, a culture of bacterial cells is infected. The bacterial cells that have successfully acquired the plasmid containing the gene are grown as a pure cell culture. A culture is a clone of identical cells. Each

different clone possesses a different gene. From the many clones, the specific clone containing the gene of interest is selected. There are many different ways to transfer genes, each with their unique challenges depending on the type of cells. Upon successful gene transfer, a genetically modified organism has been created.

GM foods have stirred controversy on the basis of health or environmental concerns. As public awareness of GM foods has increased, many countries have enforced mandatory labeling laws for GM food. Many of the advocacy groups argue that labeling GM food is necessary for consumer choice. However, groups that oppose labels argue that a law would eliminate consumer demand for GM crops, cause sharp increases in resource utilization, and raise food prices. The debate over GM foods is still active as the public has become more aware. The scientific community has largely come together and concluded that the consumption of GM foods is no more dangerous than eating traditionally selected crops. However, there is evidence suggesting potential environmental impacts of GMOs.

The field of genetic engineering is rapidly developing each year with promising biotechnology systems such as CRISPR. In June 2012, researchers targeted the CRISPR system toward specific DNA sequences, showing its potential for genome editing. In January 2013, CRISPR was used on human and mouse cells. In March 2015, there was a report of the first CRISPR gene drive that could spread rapidly through a population. In April 2015, researchers reported that they edited human embryos with CRISPR. Unlike other gene-editing methods, CRISPR is relatively easy to use and quick. CRISPR can potentially accelerate the gene therapy field, making it possible to cure genetic diseases; however, some scientists fear that the accelerated development of CRISPR may leave little time to address safety and ethical concerns. James Wilson, a medical geneticist of the University of Pennsylvania in Philadelphia, has stated that the CRISPR field is still young, and it could be years before its potential is realized.

Mubarak Alhassen

See also Vol. 3, Sec. 3: Genetically Modified Foods

Further Reading

- Dale, Philip J., Belinda Clarke, and Eliana M. G. Fontes. 2002. "Potential for the Environmental Impact of Transgenic Crops." *Nature Biotechnology* 20, no. 6.
- Ledford, Heidi. 2015. "CRISPR, the Disruptor." *Nature* 522, no. 7554: 20–24.
- Nair, A. J. 2008. *Introduction to Biotechnology and Genetic Engineering*. Hingham, MA: Infinity Science.
- National Center for Biotechnology Information (US). 1998. "Introduction to Genes and Disease." *Genes and Disease*. U.S. National Library of Medicine. January 1.
- Nicholl, Desmond S. T. 2015. *An Introduction to Genetic Engineering*. Cambridge: Cambridge University Press.

Gosling, James (1955–)

James Gosling was born on May 19, 1955, near Calgary, Canada. He is considered to be the father of the programming language Java. Even in his early years, Gosling was interested in science. While he was at the University of Calgary, he worked on a project that took data off tapes and created photographs of the Isis 2 satellite from them. While working on this, Gosling also became the local maintainer of TECO, a text editor.

Around the age of 15 or 16, Gosling created a small interpreter while working on a data analysis program. Gosling originally created this program out of frustration after many of his colleagues asked him repeatedly to make the program do several actions. He received a bachelor of science degree in 1977 for computer science from Carnegie-Mellon University, and he received his PhD in computer science in 1983. While working on his doctorate, he wrote a text editing software called Gosling Emacs and developed several electronic mail systems.

Before beginning his career at Sun Microsystems, Gosling had already created a version of *Emacs*, a text editor. However, he renamed his version *Gosmacs*. He created the Java language in 1995, plus the original compiler and virtual machine. Gosling spent a large

part of his career at Sun Microsystems—from 1984 to 2010. In 2010, Gosling encountered issues in the company where he had become a vice president and fellow; Sun Microsystems had recently been obtained by Oracle Corporation, another computer technology corporation. After this change came a legal case in which Google was accused of infringing on Oracle's patents.

Gosling has received honorary awards such as The Economist Innovation Award in 2002 and IEEE's John von Neumann Medal in 2014. He was made a fellow of the Association for Computing Machinery in 2013 and Officer of the Order of Canada in 2007. As of 2017, Gosling began working for Liquid Robotics as its chief software architect. He had written software for an autonomous oceangoing robot in 2011. Gosling has also written a number of books that pertain to his Java program, some of the most notable being *The Java Programming Language* and *The Java Language Specification*.

The Java program has had a large impact on the world of science because of its accessibility. His efforts have helped make building applications and platforms easy for computer users. Java applications are very flexible and can run on any machine. The program is also considered accessible because it is open source. Many people in the professional world and the general public have benefited from Gosling's innovations.

Monica Orozco

See also Vol. 3, Sec. 3: Google; Java

Further Reading

- "A Conversation with James Gosling." 2004. Association for Computing Machinery. <https://queue.acm.org/detail.cfm?id=1017013>, accessed September 25, 2018.
- Singh, Tejinder. "New Learning Methodology for Student of Java Programming Language." *International Journal of Engineering Research and Development* 3, no. 11: 17–19.
- Taft, Darryl K. 2010. "The Life and Times of Java and James Gosling." *eWeek*. April 13. <http://www.eweek.com/development/the-life-and-times-of-java-and-james-gosling>, accessed August 31, 2018.

IBM Personal Computer

In 1981, IBM released the first microcomputer designed for personal, individual use. By 1982, the IBM PC had taken the personal computer market by storm and was the microcomputer that set the precedent for all future personal computers. At the end of 1982, IBM was selling one unit for every three in a business day. This wildfire of success set the precedent for desktop computers made for personal rather than business use, establishing a new standard of what a computer was in the eyes of the public.

Before IBM's entry into the personal computer market, the scene was quite small. In fact, Apple may have been the only major player during that time with its then relatively successful Apple II personal computer. IBM had been trying for years to break into that

market with no luck, and after many attempts to create a profitable working prototype failed, many people in IBM believed that creating a personal computer in-house was not possible. There was much opposition when there was talk in IBM about finally designing a personal computer in 1980.

Why did it again try something that many had proven expensive and unprofitable? Just one year prior, IBM did something out of the ordinary and outsourced the processor for one of its experimental computers, the "Datamaster." Traditionally, IBM used processors designed in-house. But it now saw the benefits of outsourcing from Intel: its processors were much more powerful. IBM was then able to design the IBM 5150 personal computer, the model that would set the precedent for future personal computers.



The IBM AT (Advanced Technology) model personal computer was the second-generation IBM personal computer. It became available to the public in 1984. (Bettmann/Getty Images)

After developing the “Datamaster,” IBM outsourced other computer components. IBM CEO Frank Carey encouraged the idea of making a personal computer that was as open in architecture as possible. By August 1980, more than 500 engineers, programmers, planners, marketers, and managers were assigned to the IBM 5150 model project, again using Intel processors. IBM was now familiar with the chipset, and Intel was willing to cut a good deal.

The operating system (OS) for the IBM 5150 was outsourced from Microsoft. Microsoft’s MS-DOS operating system already had professionally published manuals on how to develop software for it, and IBM wanted to encourage third-party developers. The company also marketed its own programs. In a press release on August 12, 1981, IBM vice president C. B. Rogers Jr. said, “We intend the IBM Personal Computer to be the most useful system of its kind. Besides making it easy to set up and operate, we are offering a program library that we expect will grow with the creativity of the personal computer users.” This was very important for the success of the IBM personal computer because at the time, businesses were the main purchasers of computers, and their main motivation to buy them was to use business-focused software like *VisiCalc*.

The Apple II was IBM’s main competitor. Businesses bought the IBM 5150 because of its software, including a program that stored text for editing and printing, as well as video games like *Microsoft Adventure*, where players explored caves in search of treasure. IBM marketed the 5150 as the first computer truly designed for personal, individual use. IBM constrained the proportions of the model 5150 to fit on a desk. This parameter was very important; it set the standard for how computers would look in the future.

The IBM personal computer was seemingly an overnight success. Businesses everywhere were excited about its open-endedness. Over its five-year life span, the IBM 5150 sold about 3 million units—about 2.75 million more than the company had predicted. In one month alone in 1984, it sold about 250,000 units.

The IBM personal computer set the standard for obtaining components and software from several sources that we follow today. Although there are many

computer brands now, they all use processors from Intel and AMD and graphics cards from NVidia. The ability to handle a very large array of software is essential in personal computers today, from the Microsoft Office suite to current commercial video games.

Michael Yu

See also Apple; Dell, Michael “Saul”; Microsoft

Further Reading

Bradley, D. 2011. “A Personal History of the IBM PC.” *Computer* 44, no. 8: 19–25.

Bride, E. 2011. “The IBM Personal Computer: A Software-Driven Market.” *Computer* 44, no. 8: 34–39.

Bunnell, David. 1982. “Boca Diary.” *PC: The Independent Guide to IBM Personal Computers*: 21–27.

Infant Formula

Infant formula is a powdered substitute for breast milk for feeding infants. Pediatricians generally advise exclusively breastfeeding for the first 12 months of an infant’s life; however, the pace of modern life means that many infants are formula fed today, at least in part, in their first months of life.

For years, researchers have studied the possible benefits of certain fatty acids naturally delivered to babies through breast milk. They tested added fatty acids in infant formula such as DHA (omega-3) and AA (omega-6). DHA and AA are long-chain fatty acids and constituents of fats and lipids. DHA and AA are vital to normal human physiology; they influence membrane “traffic.” The molecules of these particular fatty acids are long chains of lipid-carboxylic acid found in fats, oils, and cell membranes as a component of phospholipids and glycolipids. Fatty acids that are added to infant formula come from animals, most often cows, and vegetable fats and oils. Essential fatty acids are polyunsaturated fatty acids that are synthesized by plants but not the human body and are therefore a dietary requirement.

Numerous studies have compared the red blood cell fatty acid profiles of breastfed and formula-fed

infants and have found that supplementation of infant formulas with DHA and AA results in red blood cell fatty acid profiles extremely similar to those of breast-fed infants and receive the same benefits. It is important to supplement with both DHA and AA, as providing one but not the other produces a state of imbalance.

Although breastfeeding is best for an infant because it contains the perfect amount of antibodies, water, carbohydrates, fat, protein, vitamins, and minerals, some mothers cannot produce milk, or their busy lives prevent them from feeding a newborn. Mothers who cannot breastfeed their babies choose infant formula as their second option. It is important for infant formula to contain the proper ingredients and nutrients (and for parents to know what these are); otherwise, it could be fatal for the infant. Nowadays, infant formula is better at matching the ingredients and proportions of human milk, and infant mortality rates have decreased drastically in recent decades.

Rosanne Welch

See also *Vol. 2, Sec. 1: Food Preservation; Vol. 2, Sec. 3: Freeze-Dried Food; Vol. 3, Sec. 3: Genetically Modified Foods*

Further Reading

“Efficacy and Safety of Long-Chain Polyunsaturated Fatty Acid Supplementation of Infant-formula Milk: A Randomised Trial.” 1999. *The Lancet* 354, no. 9194: 1948.

Gibson, Robert, Denis Barclay, Helen Marshall, Julie Moulin, Jean-Claude Maire, and Maria Makrides. 2009. “Safety of Supplementing Infant Formula with Long-Chain Polyunsaturated Fatty Acids and Bifidobacterium Lactis in Term Infants: A Randomised Controlled Trial.” *British Journal of Nutrition* 101: 1706–13.

Morris, G., J. Moorcraft, A. Mountjoy, and J. C. Wells. 2000. “A Novel Infant Formula Milk with Added Long-chain Polyunsaturated Fatty Acids from Single-Cell Sources: A Study of Growth, Satisfaction and Health.” *European Journal of Clinical Nutrition* 54, no. 12: 883.

Insulin Pump

The NASA-inspired insulin pump is one of the greatest examples of innovation from space technology transferred to the medical field. The insulin pump is a small device about the size of a wallet and contains insulin. The pump has buttons and a screen used to monitor and program how much and when to administer the insulin. The pump has improved the lives of millions of patients who suffer from diabetes.

The earliest insulin pump was invented by Dr. Arnold Kadish in 1963. It was roughly the size of a backpack, however, and it was extremely heavy and expensive. In 1976, Dean Kamen invented a portable infusion pump. NASA’s Viking program, which sent space probes to Mars, provided the inspiration for the insulin pump. The probes had fluid control systems to monitor the many fluids that they required to function, and the systems would replenish them when necessary and allowed the probes to deliver liquid into Martian soil to cultivate microorganisms there.

Before the NASA-inspired insulin pump, people with diabetes had to monitor their blood glucose level manually, pricking their fingers and reading their glucose level from the blood sample with a meter. They sometimes had to do this somewhat painful and unsanitary test up to six times a day.

On November 10, 1986, doctors at Johns Hopkins University successfully implanted the new space-age insulin pump underneath the skin of a man’s stomach. This pump was designed to be very long lasting and could be reprogrammed without removal with another surgery. It monitored the patient’s blood glucose level constantly and consistently, saving the patient from having to do it many times a day. The new pump let patients control insulin delivery with the touch of a button and at precise doses. That is difficult to do manually. People could now manage their diabetes better and protect themselves from its many risks.

The insulin pump inspired by NASA technology has since been improved and positively affected the lives of millions who suffer from diabetes. It provides a much safer way for patients to test themselves and administer insulin with a lower risk of infection. What once was a difficult, dangerous, and time-consuming

treatment is now as easy as pressing a few buttons to keep healthy.

Peg A. Lamphier

See also *Vol. 3, Sec. 1*: “Air” Athletic Shoes; National Aeronautics and Space Administration (NASA)

Further Reading

Bijllefeld, Marjolijn, and Robert Burke. 2003. *It Came from Outer Space: Everyday Products and Ideas from the Space Program*. Westport, CT: Greenwood Press.

Husted, Bill. 2016. “The Space Program: What Good Is It?” *The Atlanta Journal-Constitution*, F.1.

“NASA-Style Pump Is Implanted in Diabetic.” 1986. *New York Times*, August 8.

Internet

The Internet is a series of computer networks connected together on a global scale. Through this “internetting” of networks of devices worldwide, users can interact with each other no matter where they live or work. The internetting of networks, or “Internet,” started out as research commissioned by the U.S. government in the 1960s to find a way to communicate across computer networks. In response to this, the U.S. Defense Advanced Research Projects Agency (DARPA) was commissioned in the 1970s to investigate techniques and technologies to interlink packet networks.

The concept was then used by Tim Berners-Lee, inventor of the Internet, to create the World Wide Web (WWW) in the late 1980s. This British computer scientist had parents who were among the earliest computer scientists working on the first computer. He graduated from Oxford University in 1976 and immediately found a job as a software engineer for the Conseil Européen pour la Recherche Nucléaire (CERN), which at the time had a large particle physics laboratory in Geneva, Switzerland. It was there that Berners-Lee thought of the World Wide Web as a way to pass along information of all sorts. Due to Berners-Lee’s idea of sharing information at a much faster pace, the Internet and the World Wide Web have become the giant communications tool we know today.

When DARPA initiated the research for interlinking packet networks, its objective was to create a communication protocol that would allow one networked computer to communicate across multiple linked networks. This protocol is known as the TCP/IP Protocol Suite or the “Internet Protocol suite.” The earliest precursor network, called ARPANET, was used by military and regional academic networks to interconnect with other computers.

Berners-Lee used this process of linking computers together to speed up the sharing of information. Working as a software engineer for CERN, he noticed that there was a problem with acquiring information. He noticed that different information was stored on different computers and that multiple log-ins on multiple computers were required just to retrieve and share it. Oftentimes, computers used different programs, making sharing information harder because the operator had to know how to use them all.

Berners-Lee solved the problem by exploiting a database format called hypertext, which displays text on a computer screen that links topics and refers to other texts. Trying to capitalize on this new idea, in March 1989, he submitted his initial proposal, but it was soon rejected. It wasn’t until the 1990s when he redistributed it that his manager at the time, Mike Sendall, accepted the proposal. By the next month, he had written three essential pieces of computer code that we need even today:

- **HTML:** Hypertext Markup Language. The markup (formatting) language for the Web.
- **URI:** Uniform Resource Identifier. A kind of “address” that is unique and used to identify each resource on the Web. It is also commonly called a “URL.”
- **HTTP:** Hypertext Transfer Protocol. Allows for the retrieval of linked resources from across the Web.

In the mid-1990s, the popularity of the Internet grew. Starting from the United States, it spread to the developing world in the late 1990s. Today, the Internet has grown into an all-in-one destination for accessing information of almost any kind, with e-mail, search engines, and streaming video services being used by

more households than Berners-Lee might ever have imagined. The Internet has redefined traditional communication media like mail, the telephone, radio, television, and newspapers, upgrading immediacy and efficiency. In the attempt to find the true potential of the Internet, Berners-Lee made it free for anyone and everyone to access the “Web.”

At the Massachusetts Institute of Technology in 1994, Berners-Lee founded W3C, an organization composed of several companies with the intention of improving the Web by setting standards. This was when Berners-Lee decided to make the Web free for everyone to improve upon and realize its full potential. In 1999, Berners-Lee wrote an autobiography—*Weaving the Web*—about how he came up with the idea. In it, he recounts the events that led him to the creation of the Web, discusses his vision for it, and addresses issues including censorship and privacy, plus his plans for the future of the World Wide Web.

Net neutrality is the principle that Internet service providers must treat all data on the Internet the same—that they cannot discriminate or charge differently by user, content, Web site, platform, application, type of attached equipment, or method of communication. In December 2017, the U.S. Federal Communications Commission voted to repeal the net neutrality order it had issued in 2015.

John A. Francisco

See also Berners-Lee, Tim

Further Reading

- Berners-Lee, Tim. 2000. *Weaving the Web: The Original Design and Ultimate Destiny of the World Wide Web*. New York: Harper Business.
- Hillston, Kevin. 2005. *The Internet Revolution*. n.p.: Omnigraphics.
- Isaacson, Walter. 2014. *The Innovators: How a Group of Hackers, Geniuses, and Geeks Created the Digital Revolution*. New York: Simon & Schuster.

Jobs, Steve (1955–2011)

Steve Jobs was the CEO of Apple Computer and the innovative creator of the Macintosh computer, the

iPod, the iPhone, and the iPad, devices that have revolutionized the way Americans communicate and interact with information.

Beyond creating products that reoriented the computer and cell phone industries, Jobs revolutionized recorded music through iTunes, which allowed inexpensive online delivery of music as an alternative to piracy and led to the decline of the CD. He played a major role in Pixar’s transformation of the methods for creating animated films, initiated with the Academy Award–winning *Toy Story* in 1995.

In all his projects, he was known as obsessive in his focus on aesthetic design and attention to detail to enhance the user’s experience. Even though he was accused of micromanaging during his lean years, most came to value his outlook as essential to the success of his products. He had a role in everything from the design of packaging to the look of the Apple Store. The Museum of Modern Art holds 25 Apple products in its design collection.

Jobs is credited as the inventor or coinventor in 338 U.S. patents or patent applications. Even though he earned only \$1 a year as Apple CEO, his ownership of Apple and Disney stock gave him an estimated 2010 wealth of \$8.3 billion, causing *Forbes* magazine to list him as the 42nd wealthiest American at the time. Apple’s iPad tablet, now in its third generation, is currently outselling the number of personal computers being sold by any manufacturer; Apple has sold 58 million iPads since they were first introduced in 2010. Revenue from iPad sales and from the iPhone has made Apple “the most valuable company in the world, with a market capitalization of almost half a trillion dollars, well ahead of its nearest rival, Exxon Mobil,” according to a report in the *New York Times* on the occasion of Apple’s introduction of the third version of the iPad on March 7, 2012.

Jobs began his computer career after dropping out of Reed College and quitting a position as a video game designer at Atari, and after travel to India, an experience that contributed to his conversion to Buddhism. He and Steve Wozniak, a school friend and computer engineer, created the first small, accessible, and inexpensive personal computers, the Apple I in 1976 and, three years later, the Apple II. They are

credited with revolutionizing the industry by offering a true user-friendly personal computer.

Selling for \$666.66, Apple I sales totaled \$774,000, but the Apple II increased revenue 700 percent to \$139 million because it offered color graphics, expansion slots, and primarily the ability to run *Visi-Calcul*, the first computer spreadsheet that made the devices so valuable to business. The company went public in 1980 and achieved a market value of \$1.2 billion on the first day of trading. That year, Jobs brought in a marketing expert, John Sculley of Pepsi-Cola, as president.

The Macintosh computer was released to great fanfare in 1984 with a famous Super Bowl commercial that alluded to the George Orwell novel and depicted a female runner who carried a large hammer breaking free of the Big Brother enslavement of the unnamed but implied IBM personal computer. Despite the success of the commercial and the praise of its design, the Macintosh could not compete with IBM, which dominated business computing, because their operating systems were not compatible.

A series of disappointments soured the relationship between Jobs and Sculley, leading Apple's board to relieve Jobs of his operating responsibilities when it reorganized the company in May 1985. Sales of the Macintosh computer, introduced the year before, were very disappointing, far below expectations. The company was facing the first financial loss in its history. Jobs resigned from Apple in September of that year to start a new computer company called NeXT, which was aimed at producing a computer adapted to the special needs of higher education.

He spent the next 12 years at NeXT in what was a period of failed expectations and flawed business decisions. When released to the market in 1988, the computer cost \$6,500, plus another \$2,000 for its printer, compared to the discounted educational price of \$1,000 for a Macintosh. Academic budgets could not afford it, and after selling only 50,000 units in the following seven years, Jobs ended production.

While a commercial disaster, NeXT ended up as a technological success in the design of its UNIX-based software that became the source of the Macintosh's new operating system, Mac OS X. While at NeXT, Jobs also made his very successful investment in Pixar, an initially struggling company that he eventually sold

to Disney for \$7.4 billion. NeXT was sold to Apple in 1996 for \$429 million, and Jobs was brought back to the company as temporary de facto chief and in 1997 formally as chief executive.

The relationship of Jobs and Apple mirrors mythic patterns, from rise to fall to triumphant return. After his return, Jobs also took a company many considered economically moribund, possibility doomed, and made it at the time of his retirement announcement Exxon's competitor for the prestige of being the world's wealthiest corporation. Measured quantitatively by stock value, the final decade of Jobs's leadership had been a phenomenon. In 10 years, he took the value of the company from \$9 a share to \$376 on the day he stepped down. As *Businessweek* noted just hours after Jobs's death, "Apple's stock price has risen more than 9,000 percent since Jobs returned to the company in 1997." Qualitatively, Apple's recent innovations had changed the nature of computing from a machine on a desktop to a device that fits into the palm of a hand.

Jobs's return to the leadership of Apple resulted in innovations that exceeded all expectations. Yet, ironically, at the height of his success and adulation by Apple devotees, he suffered severe medical problems. He had a first surgery for pancreatic cancer in 2004 and a liver transplant in early 2009, debilitations that led him to give up the leadership of his company and resulted in his death.

The details of Jobs's personal life have not been widely known, and he made efforts to maintain privacy. He was born on February 24, 1955, to parents who were, at the time, graduate students at the University of Wisconsin: Joanne Schieble and Abdulfattah "John" Jandali from Syria, who became a professor of political science. They gave him up for adoption before he had a name, and Jobs was unable to discover the details of his biological parentage until he was 27. He was named Steven Paul Jobs by his adoptive parents, Clara and Paul Jobs. His mother worked as an accountant, and his father was a Coast Guard veteran and machinist who introduced Jobs to electronics through experiments in the family garage, the same garage where the Apple computer was created.

Jobs's biological parents did marry after the death of Joanne Schieble's father, who had opposed the marriage. They had a second child, the novelist Mona

Simpson, who took the name of her stepfather, her mother's second husband. Simpson's novel *A Regular Guy* features a character much like Jobs in an unflattering portrait. Yet the siblings became very close and were in frequent contact.

When he was 23, Jobs and Chrisann Brennan, an artist, had a daughter, Lisa, whose parentage he initially denied for seven years. However, she came to live with him as a teenager. He married Laurene Powell on March 18, 1991, and fathered a son and two daughters. They lived in Palo Alto, California.

Jobs has been compared with Thomas A. Edison as an archetypal American inventor, a man whose innovations revolutionized a society. In many ways, that linking is an exaggeration. Edison, in devising the phonograph, a functional electric lightbulb, and the motion picture camera, brought fundamental changes to American and world society—the ability to overcome darkness with electrical illumination and to record and preserve sound and movement. Jobs enhanced existing technologies with results that transformed the ways in which people interact with devices and information and also produced major effects on a number of businesses.

Rather than the link to Edison, a more relevant comparison may be with Microsoft's Bill Gates, a man of the same generation, also born in 1955 and also essential to the computer revolution. The two men and their companies have been considered major competitors by industry watchers. Yet they followed very different business models and lived very different personal lives. Still, their ascendancy made them contrasting heroes and villains to many. Ironically, those roles shifted with the fortunes of their companies: the greater the success, the more the criticism of the man.

In many ways, Gates deserves credit for the ubiquity of the computer in our lives. He organized the development of the operating systems—from MS-DOS to Windows—that made computers more functional and allowed the products of different manufacturers to interact. But those in the field criticized his programs for their cumbersome coding, their propensity to crash, and their vulnerability to viruses. Microsoft was attacked for predatory practices, using its wealth and power to put smaller companies out of business by offering for free what others had to charge

for. Yet it kept accumulating profits by licensing its programs to computer makers through the world, to the point where more than 80 percent of all computers run on Microsoft software.

Apple, on the other hand, created its own hardware as well as operating software that differed greatly from that of Microsoft. A more important difference—except for one brief attempt—was the decision not to license its software to other manufacturers. Those in the field agreed that the Apple system and equipment were more elegant, trouble free, and easier to use. At the same time, Apple computers were more expensive and, more significantly, for many years did not interact smoothly with the great majority of Microsoft-based computers. Apple served a niche market, appealing especially to those who worked in graphic design and layout. But business and education in general found Apple too specialized for adoption.

Microsoft tacitly admitted that Apple technology was superior, developing its own software to emulate Apple features. For example, Apple was the first with a mouse and a graphic user interface (GUI), substituting clicking on an icon for several steps of keyboard combinations. Microsoft devised the first Windows software to compete and since then has kept up with, and in some cases surpassed, the latest Apple features.

It has been the iPod, and then the iPhone and iPad, that converted large numbers of people to Apple believers. They liked the designs, the quality, and the ease of operation. When Apple opened Apple Stores, people flocked to sample the equipment and to be served by a friendly, knowledgeable staff. Those stores have in themselves become models for other retail operations. Apple computers still are a minority of those sold today, just 10 percent of the U.S. market. The company makes most of its profits from iPhones and iPads—for example, selling 20.34 million iPhones and 9.25 million iPads as compared to 3.95 million Macs in the quarter reported in the company's July 19, 2011, report.

In one of his last public appearances as Apple's CEO to announce a pending new operating system for the company's portable devices and its new approach to cloud computing, the iCloud, Jobs predicted the demise of the computer as a dominant force. The cloud, versions of which already were available,

enables people to store music, video, and data files on distant servers rather than personal computers. All of this information is also accessible on multiple portable devices. Again, Apple took the lead in a direction for computing that may result in a fundamentally new way of interaction in the way that the iPod did with recorded music.

But as Apple rose from an orphaned favorite of technological purists to dominance, wealth, and power, attacks on Steve Jobs accelerated. For years, Bill Gates was castigated for his great wealth, excessive mansion, bland personality, and roughshod tactics. But now that the Bill & Melinda Gates Foundation offers grants from the couple's billions to fight disease and further throughout the world, Gates is no longer disdained.

Apple and Jobs exchanged places for the critics, with Jobs seen as domineering for his rigidity in keeping Apple a "closed" company. Its software codes are tightly guarded. Those who revealed photos and details about a found iPhone prototype were sued and lost the case. Apps proposed by the iPhone and iPad are carefully screened before their sales are allowed. Yet, in the days after his death, only the voices of praise for Jobs were heard.

The day Steve Jobs announced that he was stepping down as CEO of Apple on August 25, 2011, David Pogue of the *New York Times* said of him:

His personality made Apple Apple. That's why no other company has ever been able to duplicate Apple's success. Even when Microsoft or Google or Hewlett-Packard tried to mimic Apple's every move, run its designs through the corporate copying machine, they never succeeded. And that's because they never had such a single, razor-focused, deeply opinionated, micromanaging, uncompromising, charismatic, persuasive, mind-blowingly visionary leader.

Pundits immediately asked whether Apple could maintain the same levels of unprecedented inventive and financial success without Jobs's leadership. Jobs died on October 5, 2011, of the pancreatic cancer that had caused him to resign, one day after the company's

first major product announcement without him. The world's broadcast, digital, and print media were immediately overwhelmed with encomiums to the man and his achievements. He was called the best CEO of the past 50—perhaps 100—years by Google chairman Eric Schmidt.

Jobs's list of accomplishments began when he was just 21 with the introduction of the Apple computer, which was followed by the breakthrough Macintosh and more recently the iPod, the iPhone, and the iPad. Joe Nocera of the *New York Times* called them "more than devices. They were objects of lust."

One researcher even argues that iPhones have become objects of love rather than addiction. Martin Lindstrom, an expert on consumer behavior, gave subjects functional magnetic resonance imaging tests to measure their brain activity as they were shown images of products like the iPhone and also religious images such as rosary beads. He found "uncannily similar" brain activity: "In short, the subjects didn't demonstrate the classic brain-based signs of addiction. Instead, they *loved* their iPhones." If Lindstrom is correct, Steve Jobs is responsible for an unprecedented achievement in American life.

Walter Cummins

See also Apple; Apple II; Computer/Information Technology; Dell, Michael "Saul"; IBM Personal Computer; Kare, Susan; Microchip; Microsoft; Open-Source Software; Wozniak, Steve; *Vol. 3, Sec. 1:* Fortran; *Vol. 3, Sec. 3:* iPod; Linux; Wang, An; Williams, Roberta and Ken

Further Reading

"Apple Boosts Market Share in Slumping U.S. PC Market." 2011. *MacRumors*, January 13. <http://www.macrumors.com/2011/01/13/apple-boosts-market-share-in-slumping-u-s-pc-market/>, accessed August 31, 2018.

"Apple Reports Third Quarter Results." 2011, July 19. <http://www.apple.com/pr/library/2011/07/19Apple-Reports-Third-Quarter-Results.html>, accessed August 31, 2018.

Galloway, Scott. 2017. *The Four: The Hidden DNA of Amazon, Apple, Facebook and Google*. New York: Portfolio Books.

- Kocienda, Ken. 2018. *Creative Selection: Inside Apple's Design Process During the Golden Age of Steve Jobs*. New York: St. Martin's Press.
- Lindstrom, Martin. 2011. "You Love Your iPhone, Literally." *New York Times*, October 1, A21.
- Pogue, David. 2011. "Steve Jobs Reshaped Industries." *New York Times*, August 25. <http://pogue.blogs.nytimes.com/2011/08/25/steve-jobs-reshaped-industries/>, accessed August 31, 2018.
- "Steve Jobs Biography." <http://www.biography.com/people/steve-jobs-9354805>, accessed August 31, 2018.
- Wingfield, Nick. 2012. "Apple Adds Sharper Screen and Speed to New iPad." *New York Times*, March 8, B1.

Kare, Susan (1954–)

Susan Kare is an artist and graphic designer who started her career with Apple Macintosh. She is responsible for many of the interface elements on the Apple Macintosh in the 1980s.

Kare was born in Ithaca, New York, in 1954. In 1971, Kare graduated from Harriton High School and moved on to Mount Holyoke College and completed a BA in art in 1975. Kare finished school with a PhD in fine arts from New York University in 1978. Once finished with college, she moved to San Francisco and worked in an art museum. Kare has a husband and three sons.

Kare joined Apple Computer in the early 1980s after a friend from high school phoned her about a position. Originally hired to design user interface graphics and fonts, Kare became the creative director for Apple from 1982 to 1985. She designed icons, typefaces, and marketing material for the original Macintosh operating system. Kare created the grabber, the bomb, the lasso, the paint bucket, the Geneva and Chicago typefaces, the command signal, and Clarus the dog (an indicator of pages printing horizontally or vertically). Frequently used icons created by Kare were the Mona Lisa face (indicating a working computer), the happy Mac (a smiling computer greeting users), the trash can, and the clock (letting users know the computer is busy and cannot be used).

In 1985, Susan Kare left Apple and joined Steve Jobs's company NeXT as a designer. Kare began working with clients such as IBM and Microsoft. She would also design several icons as an independent graphic designer and designed a deck of cards for Windows Solitaire. In 2007, Facebook released gifts designed by Karen that could be purchased for a dollar. The gifts were a success on Facebook, causing Kare to create limited edition gifts. In 2015, Kare was hired by Pinterest as a lead product designer. Pinterest planned to assign her tasks such as designing buyable pins, app pins, refined interfaces, and a guided search.

Currently a partner in Susan Kare LLP, Kare is also a cofounder for Glam.com and a creative director for Chumby Industries Inc. Designs of Kare's stationery and notebooks are exhibited in the Museum of Modern Art store in New York City. Kare has her own digital design company in San Francisco, where she sells limited edition signed prints and fine art. Her icons have been used on more than computers. Prints of them have been put on shirts and displayed in the *New York Times Magazine* as well as on paper as art that is hung on walls. Kare's icons have become famous for their ability to communicate their function instantly and memorably, with wit and flair.

Rachel Alzaga

See also Apple; Computer/Information Technology; Jobs, Steve; *Vol. 3, Sec. 1*: Intel Corporation

Further Reading

- Hertzfeld, Andy. 2004. *Revolution in The Valley: The Insanely Great Story of How Mac Was Made*. Sebastopol, CA: O'Reilly Media.
- Meggs, Philip B., and Alston W Purvis. 2012. *Meggs' History of Graphic Design*. New York: John Wiley & Sons.

Laser Cataract Surgery Device

The Laserphaco Probe is a medical device that ablates and removes cataracts from eye lenses with a laser through a relatively painless process. Originally conceived in 1981, it was later patented in 1988 by the ophthalmologist Patricia Bath, the first African

American female doctor to receive a patent for a medical invention.

Patricia E. Bath was born on November 4, 1942, in Harlem, New York. The daughter of an immigrant from Trinidad and a woman descended from African slaves and Cherokee Native Americans, Patricia grew surrounded by the sexism, racism, and poverty that were often present in Harlem in the 1950s and 1960s. Her parents strongly encouraged her toward an academic career, and when she was just 16, she became one of the few students selected to attend a cancer research symposium promoted by the National Science Foundation. Bath graduated from high school in just two years and then attended Howard University, where she received her medical degree with honors in 1968.

During her early career at the Harlem Hospital, Bath discovered that blindness among African Americans was double that among all other patients. To address this issue, she proposed the development of a new discipline, community ophthalmology, to increase the amount of eye care provided to underserved populations. After joining the faculty of University of California, Los Angeles and Charles R. Drew University in 1974, Bath was the first woman in the United States to be appointed chair of ophthalmology in 1983.

In 1981, she started working on her best-known invention, the Laserphaco Probe, a new method to remove cataracts that was well ahead of its time. In the next five years, she took her research abroad to the Laser Medical Center of Berlin in Germany, where she learned more about laser science. The device was completed in 1986 and later patented on May 17, 1988. The Laserphaco Probe is still used worldwide to restore sight to countless patients and has been substantially improved since its invention. The laser can, in fact, dissolve the cataract by vaporizing it, and it's much more reliable, fast, and accurate than the traditional drill-link devices used in ophthalmic surgery. The Probe also includes a system that irrigates and cleans the eye, and suction tubes to remove the ablated lens material.

In 1993, Bath retired from the UCLA Medical Center and was then the first woman to be appointed to the honorary medical staff. Shortly afterward, she was named a Howard University Pioneer in Academic

Medicine. In May 2001, Bath was also inducted into the International Women in Medicine Hall of Fame. Today, she continues to advocate vision care through telemedicine, using telecommunications technology to provide medical services outreach to remote areas.

Claudio Buttice

See also Elion, Gertrude; *Vol. 2, Sec. 3*: Clarke, Edith

Further Reading

Farmer, Vernon L., and Evelyn Shepherd-Wynn. 2012. *Voices of Historical and Contemporary Black American Pioneers*. Santa Barbara, CA: ABC-CLIO.

Sullivan, Otha Richard, ed. 2001. *Black Stars: African American Women Scientists and Inventors*. Hoboken, NJ: John Wiley & Sons.

Metcalf, Robert (1946–)

Robert Melancton Metcalfe, nicknamed “Bob,” is a world-famous electrical engineer from the United States. His projects have included Ethernet, founding 3Com, and formulating Metcalfe’s Law. He has worked for major technology concerns such as the Massachusetts Institute of Technology (MIT) and Xerox. At Xerox, he developed his most important project, Ethernet, in 1973. In January 2011, he joined the University of Texas at Austin in the position of professor of electrical engineering and director of innovation.

Metcalf was born on April 7, 1946, in Brooklyn, New York, and grew up on Long Island. His father is also an engineering technician. In 1964, he graduated from Bay Shore High School and entered the Massachusetts Institute of Technology (MIT), class of 1968. But he graduated in 1969 with two bachelor of science degrees: one in electrical engineering and the other in industrial management. For his master of science degree, he went to Harvard and majored in applied mathematics, finishing in 1970, and earned his PhD in computer science there in 1973.

While Metcalfe was earning his PhD, he worked at MIT because Harvard refused to let him connect the school network to the ARPANET. Metcalfe’s job was

with MIT's Project MAC, to build hardware that could link all of MIT's minicomputers with ARPANET. After a few failures, he was successful after he read a paper about the ALOHAnet at the University of Hawaii. He fixed the bugs in the ALOHA network, which helped him in his PhD work at Harvard. He then worked at Xerox PARC, where he invented Ethernet with David Boggs.

Computers sent data and signals to modems through Ethernet cables, which converted the signals to analog signals that could be transferred through existing phone wires. This is very similar to how a telegraph machine works. On May 22, 1973, Metcalfe documented the invention of Ethernet. Ethernet initially was for connecting computers over short distances, but it also allows more remote computers to communicate. For example, to download a file from an e-mail account, one computer sends a signal to the other to let it know that a file should be downloaded from its drive to the remote drive. Ethernet lets users send data to each other.

After he documented his invention, Metcalfe, David Boggs, and Tat Lam had built the first Ethernet prototype, which had a maximum speed at 2.94 Mbps. After three years of improvements, Metcalfe and Boggs published "Ethernet: Distributed Packet Switching for Local Computer Networks." In 1978, Xerox invented the X-Wire, which can run up to a 10 megabyte-per-second (Mbps) Ethernet on a coaxial cable.

After all these inventions, Metcalfe founded 3Com to commercialize Ethernet in 1979. In February 1980, the Institute of Electrical and Electronics Engineers (IEEE) started on project 802 to standardize local area networks. Then, Metcalfe asked Gordon Bell, who worked at Digital Equipment Corporation (also known as DEC), David Liddle at Xerox, and Phil Kaufman at Intel to join him to develop Ethernet based on the invention of X-Wire. The group of four experts was called "DIX." After a year of researching, the group published the "Blue Book," which contains Ethernet specifications.

Many computer hardware companies started to produce Ethernet materials and products to the world and to the DIX group for further development. More people were getting into the development of Ethernet.

Grand Junction Networks was founded to develop Fast Ethernet products that could provide high-speed Internet exchanges up to 100 Mbps. In 1998, Ethernet made history and turned 25 years old.

For Metcalfe's success, he was awarded the IEEE Medal of Honor in 1996 for "exemplary and sustained leadership in the development standardization, and commercialization of Ethernet." In May 2007, he was inducted to the National Inventors Hall of Fame in Akron, Ohio, for his invention of Ethernet, which still brings people fast networking today.

Rosanne Welch

See also *Vol. 1, Sec. 3: Telegraph; Vol. 3, Sec. 1: ARPANET; Intel Corporation; Xerox Corporation*

Further Reading

Cerf, Vint, and Bob Kahn. 1974. *A Protocol for Packet Network Intercommunication*. <http://www.cs.princeton.edu/courses/archive/fall06/cos561/papers/cerf74.pdf>.

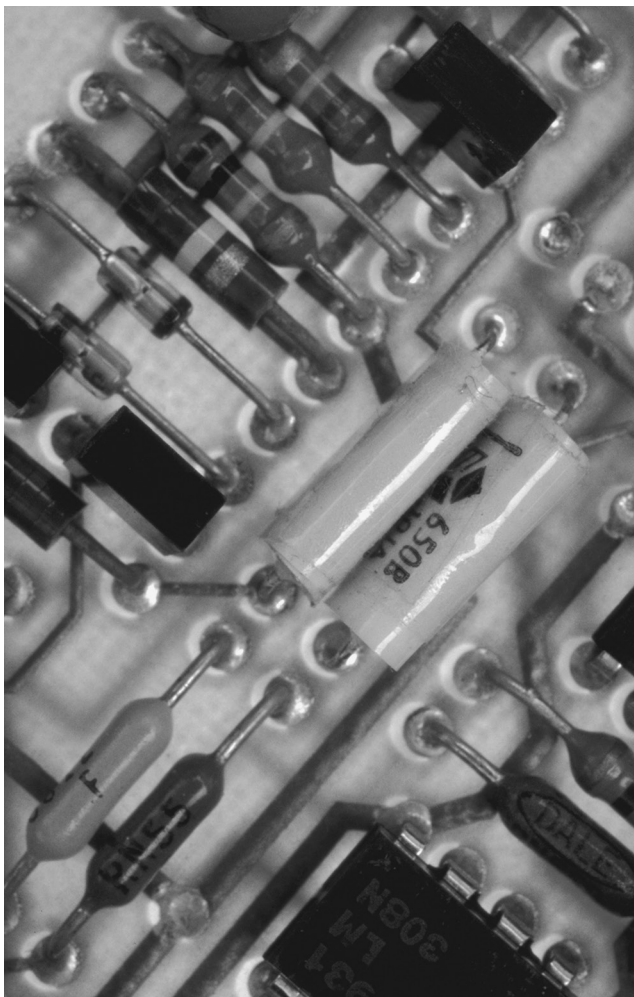
DIX Group. 1980. "Blue Book": *The Ethernet: A Local Area Network*. <http://ethernethistory.typepad.com/papers/EthernetSpec.pdf>, accessed August 31, 2018.

Metcalfe, Bob, and David Boggs. 1976. *Ethernet: Distributed Packet Switching for Local Computer Networks*. <http://ethernethistory.typepad.com/papers/EthernetPaper.pdf>, accessed August 31, 2018.

Microchip

The microchip is a collection of transistors that is the fundamental building block of all circuits and electronics in use today. These transistors lie arranged on a silicon wafer board. Since there are two possible states of being on a transistor—on and off—the nature of the silicon semiconductor is ideal for this, being able to conduct or block the flow of electricity. Different types of microchips enable the storage of various amounts of data.

The microchip was created as a result of the collaboration between Robert Noyce and electrical engineer Jack Kilby in 1958 at Texas Instruments. This wasn't an easy task. The first obstacle was the



Microchip technology lies at the heart of the computer revolution. Smaller, more powerful microchips have allowed for lighter, faster, and more powerful computers, electronic notebooks, cell phones, watches, and more. (Corel)

difficulty in creating perfect circuits to flawlessly enable the travel of electricity. It was especially difficult because circuits were made manually and soldered by hand. Due to occasional human error, electricity was not always able to traverse the circuit due to faulty connections. Additionally, these circuits had to be as small as possible to provide the speedy travel of electricity; the microchip depended on such speed to be effective.

Kilby made the first step toward the first functioning microchip when he eliminated many of the major obstacles. He is credited with the idea of putting all the necessities for a circuit on the same board. This meant

that people no longer needed to build and connect the components manually. The silicon semiconductor board improved the efficiency and accuracy of the connections.

Soon, Noyce created another functioning microchip whose model followed many of the same principles of production that Kilby's had used. Although Kilby's design had moved all the components onto a single board, they still had to be connected by wires. Noyce improved the design of the chip with a metal sheet placed on top of the circuit board; large areas of the metal sheet were then stripped, leaving behind an intricate layout of metal paths. These paths provided the connections for conducting electricity throughout the board. Noyce's design made widespread mass production of the microchip possible.

Not only did Noyce's design of the microchip change the way the components were laid out, but also, the type of materials used for production were modified. Introducing new materials into the equation allowed Noyce to overcome problems such as incidental electrical shortages within the circuit.

As with any revolutionary invention, a patent must be filed to prevent others from stealing its ideas. The patent was filed on July 30, 1959, and then published on April 25, 1961, just when some major obstacles pertaining to the production of integrated circuits had been overcome. Noyce was inspired to create an insulated surface layer for the semiconductor to adhere to oxide layers. This strengthens the electrical connections to various parts of the conductor without causing shorts between junctions.

The immense demand for microchips today has resulted in much more productive ways of generating enough to fulfill it. Modern microchips are produced layer by layer, in a process where UV light is beamed at photosensitive material over a template of the schematics. Overlapping layers of this material compose the microchip with all the correct connections. This enables mass production with enhanced precision. However, since these microchips are miniscule, even small specks of dust can ruin them. So, workers in the manufacturing of microchips must wear clean suits in clean rooms to prevent contamination. The layers of microchips are transported throughout the lab in air-tight capsules.

Microchips have become very powerful. Cofounder of Intel Gordon Moore has noted in several interviews that the number of transistors in its microchips had doubled every year. This observation is referred to as Moore’s Law. While this figure is massive, it also gives an idea of how rapidly microchip technology has improved. Due to competition and the pursuit of innovation, companies are constantly developing more efficient ways to program microchips. They are smaller but contain more transistors than ever. The microchip is a fundamental piece of technology used today in almost every electrical appliance. We can anticipate that it will continue to improve in efficiency and power.

Shinha Tsuchida

See also *Vol. 3, Sec. 1: Integrated Circuit*

Further Reading

- Bell, Michael F. 2012. *The Invisible Crime: Illegal Microchip Implants and Microwave Technology*. Mesa, AZ: Brighton.
- Brock, David C. 2010. *Makers of the Microchip: A Documentary History of Fairchild Semi-Conductor*. Boston: MIT Press.

Microsoft

Microsoft is an American technology corporation that started out writing software for the world’s first PCs with its first product, a programming language called BASIC. It continued to develop software and operating systems, making its products compatible with Internet use. The Windows operating system has been its most successful operating system, and it is used worldwide to this day.

Microsoft began in 1975 when high school friends and eventual cofounders Bill Gates and Paul Allen created and sold their first product. They developed the programming language BASIC for the Altair 8800, which was owned by Micro Instrumentation and Telemetry Systems Inc. (MITS). MITS agreed to distribute the product as Altair BASIC. Gates kept the copyright for the BASIC programming language, and Microsoft continued to develop programming

software for other systems independently from MITS. At the close of 1978, sales were above \$1 million.

Microsoft received its biggest break in 1980 when IBM requested an operating system for its new personal computer aimed at consumers. Gates purchased an operating system and sold it to IBM, calling it “MS-DOS.” It was introduced on IBM’s new personal computer. Microsoft’s collaboration with IBM was a crucial part of the growth of Microsoft. Over 150 million PCs were operating on MS-DOS at that time.

By 1985, Microsoft Windows, a graphical user interface that allowed users to connect with their PCs interactively, was shipped. Windows became the most popular user interface in computer history. Mini applications were also included in the Windows bundle, from *Notepad* to *Windows Paint*. Windows let the user control the computer with a Microsoft Mouse, but an additional innovation in keyboard commands allowed the program to be used by an even broader base of users. In 1986, the company revealed *Microsoft Works*, which had word processing, spreadsheets, databases, and drawing functions all in one program. By 1986, the company went public. In 1989, *Microsoft Office* was announced as spreading to CD-ROM and *Office 1.0* for Macintosh.

The 1990s was the Windows era. Microsoft shipped Windows 3.0 in 1990, and of course it was instantly a number-one seller. This year also marked the company’s 15-year anniversary.

By 1993, the Windows NT release allowed business applications to operate on an open, reliable platform. In 1995, the company released Windows 95 along with a Microsoft Network online service. Windows 95 successfully sold over 1 million copies within four days, and the software is the bestselling in history. The success of Windows 95 helped bring PCs into 250 million homes, businesses, and schools worldwide. That same year, with the growth and spread of the Internet, Microsoft recognized its need to adapt to the changing communication world and added Internet capabilities to all of its products. In 1997, it released Internet Explorer 4.0, which had high customer demand. At the end of the 1990s, Microsoft was making almost \$20 billion in revenue with a high growth rate and over 30,000 employees.

Throughout Microsoft history the company has partnered with unlimited number of other companies and acquired a few along the way as well. To kick off the millennium in the year 2000, Microsoft made its biggest purchase, acquiring Visio Corporation. In the same year, cofounder Gates stepped down from his position as chief executive of Microsoft to take on a new role as chairman and chief architect, becoming more involved in the development of the next-generation Windows Internet platform.

Microsoft continued to grow and flourish, and Windows continued to advance year after year. In 2001, Windows XP was released, followed by Windows Vista, Windows 7, and Windows 8 by 2011. Microsoft also entered the gaming world, introducing the first Xbox game console in 2001. New features and models followed. Soon, Microsoft was competing with international video game companies such as Sony and Nintendo.

The company also launched a Windows phone in 2011, keeping up with changing market demands. In 2008, Gates finally retired from the company, retaining his role as chairman. Most recently, Microsoft has continued to advance into the future with programs for the cloud. In 2016, Microsoft reported revenue reaching \$22.6 billion. The company continues to be a leader in computer software worldwide.

Madison Pena

See also Gates, Bill

Further Reading

- Musolf, Nell. 2008. *The Story of Microsoft*. n.p.: Creative Education.
- Schurman, Joe. 2009. *Microsoft Voice and Unified Communications*. Boston: Addison-Wesley.
- Stross, Randall E. 1997. *The Microsoft Way: The Real Story of How the Company Outsmarts Its Competition*. Boston: Addison-Wesley.

Mobile Phone

First introduced in 1973, mobile phones have become an integral part of contemporary American daily life. The mobile phone has undergone both technological

and dimension advances. From the first Motorola DynaTAC 8000x to the advent of the smartphone, the mobile phone has given us the ability to communicate wirelessly over great distances and has become vital to us.

The first mobile call was made on April 3, 1973, by a group of Motorola engineers led by senior engineer Martin Cooper. He called a rival telecommunications company and informed them he was speaking via mobile phone. It was a decade before Motorola released its first commercially available phone, however—the DynaTAC 8000x. It weighed 1.1 kilograms and measured 228.6 x 127 x 44.4 millimeters. Taking 10 hours to charge, the handset offered 30 minutes of talk time, six hours of standby, and could store up to 30 phone numbers. Early mobile phones were large and generally used in cars. They retailed for a staggering \$3,995. Despite the cost and low talk time, the demand was strong; those on waiting lists numbered in the thousands.

The DynaTAC 8000x mobile phone was launched on the United States' first 1G network by Ameritech. It cost \$100 million to develop and took over a decade to reach the commercial market. However, the first analog cellular system widely deployed in North America was the Advanced Mobile Phone System (AMPS) developed by Bell Labs and activated on October 13, 1983. AMPS suffered several issues compared to modern standards; most glaring was its unencrypted transmission, which was highly susceptible to eavesdropping via a scanner. It was vulnerable to cloning and took a significant amount of bandwidth to support its transmission of data. Many of the iconic early commercial cell phones such as the Motorola DynaTAC Analog AMPS were eventually superseded by Digital AMPS (D-AMPS) in 1990, and AMPS service was shut down by most North American carriers by 2008.

In the 1990s, mobile phones saw a new generation emerge. Two widely utilized networks competed for the ability to transmit data of this second generation of mobile phones: the European-developed GSM standard and the U.S.-developed CDMA standard, both 2G networks. Instead of transmitting data via analog signal, these networks used a more efficient digital signal. Increased efficiency and protection led to a rise in

mobile phone usage. Because of the 2G network, this era saw the advent of prepaid mobile phones.

The development of smaller mobile phones in the 1990s aided in increasing their popularity. The IBM Simon, regarded as the first smartphone, featured a touch screen. On December 3, 1992, Neil Papworth sent the first short message service (SMS) text to Richard Jarvis. It read, “Merry Christmas.” A year later, AT&T introduced the EO Personal Communicator, the first tablet computer with wireless connectivity via mobile phone line. Access to the mobile Web was a major improvement for mobile phones in the 1990s. The first access to the mobile Web was commercially offered on the Nokia Communicator 9000 and has been present on nearly all phones since.

Between 2000 and 2003, the mobile phone saw two of the biggest changes in its physical configuration. The BlackBerry 5810 made the QWERTY keyboard a popular standard, and the arrival of LCD touch screens revolutionized how users interacted with data. The smartphone as we know it today was invented. Smartphones could now download software programs known as “apps.” Several models included calendars, Web browsers, and Bluetooth capabilities, along with a host of other built-in features. The Motorola Razr V3 featured a sleek, thin design. One of the premier folding phones became Motorola’s bestselling phone ever, at more than 130 million between 2004 and 2006.

With 2G broadband growing in popularity, people began to use their phones daily, increasing demand for faster data transmission speeds. The 2G broadband could not handle the needed speeds; therefore, developers began working on a 3G network. The main difference between the two was the use of packet switching versus circuit switching. In 2007, there were 295 million 3G users around the world.

In 2008, the Apple iPhone 3G was introduced, widely considered the phone with the single biggest impact on the industry. The iPhone combined the iPod’s ability to store and play music with the wireless communication of mobile phones. It introduced people to the app store concept and made touch screens the norm.

It was clear by 2009 that the explosion of streaming media and other bandwidth-intensive applications would soon overwhelm 3G networks. The industry

thus started to develop data-optimized fourth-generation technologies, which promised a 10-fold speed increase over existing 3G technologies. The WiMAX standard (offered in the United States by Sprint) and the LTE standard (offered in Scandinavia by TeliaSonera) became the first two commercially available technologies to be billed as 4G.

4G differed technologically from 3G in its elimination of circuit switching, employing instead an all-IP network. 4G treated voice calls just like any other type of streaming audio media; it used packet switching over Internet, LAN, or WAN networks via VoIP. The main improvement with 4G over 3G technology was the ability to transmit data up to 10 times the speed of its predecessor.

With the ever-growing demand on mobile networks, coupled with technological advancements, there’s no limitation on the capabilities of future devices. Mobile phones now have access to GPS functions, which allow the phone to tell users where they are and where they want to be; Web-browsing capability; and e-book reading. Mobile phones can also be used as music listening devices, flashlights, calculators, and much, much more. The ability to send and receive information at a moment’s notice makes the mobile phone an invaluable asset in today’s society.

Peg A. Lamphier

See also Apple; IBM Personal Computer; *Vol. 3, Sec. 1: Global Positioning System (GPS); Integrated Circuit; Vol. 3, Sec. 3: e-Book and e-Reader; iPod; Smartphone and 3G Network*

Further Reading

DeVoss, Mark. 2005. “Teardown Analysis: Nor Flash Retains Mobile Place.” *EE Times*, August 4.

Farley, Tom. 2007. “Cell-Phone Revolution.” *American Heritage* (Winter).

Nuclear Energy/Nuclear Power Plants

Nuclear energy is any method of doing work that makes use of nuclear fission or fusion reactions. Nuclear energy refers to the controlled release of energy, such

as in a nuclear power plant. A nuclear power plant is a power station that has a heat source that is a nuclear reactor. The heat is used to generate steam that goes in a turbine connected to an electric generator, which produces electricity. Nuclear energy is regarded as a practical, inexpensive, and clean (emissions-free) source of energy. Today's nuclear energy production saves around 24 billion tons of carbon dioxide emissions per year that would otherwise be caused by coal-fired power generation. Fuel is a small part of the cost of producing electricity, but it is uncertain how much is spent on fuel management.

The world's first exposure to nuclear power first came when two atomic bombs were exploded over Nagasaki, Japan, and Hiroshima, Japan, in August 1945. After World War II, a number of scientists looked to harness the power of nuclear energy to perform work. They soon realized that it was difficult to get the energy they wanted. In fact, they only managed to produce a modest degree of energy from their attempts.

The first nuclear reactor was built during World War II as part of the Manhattan Project to build an atomic bomb. It was built as the first concrete test of existing theories of nuclear fission. It consisted of alternating layers of uranium and uranium oxide with graphite as a moderator or reactor core. Cadmium control rods were used to control the concentration of neutrons in the reactor. The moment that the control rods were withdrawn can be regarded as the beginning of the age of controlled nuclear power in human history.

Every power plant contains four fundamental elements: the reactor, the coolant system, the electrical power-generating unit, and the safety system. The reactor initiates and controls a sustained nuclear chain reaction. The coolant captures and transfers the heat released by fission in the nuclear reactor for use in electricity generation. The coolant also maintains manageable pressure within the core. The electrical power-generating unit converts the heat from fission to electrical energy. The amount of electricity that a nuclear reactor or power plant generates depends on the amount of time it operates at a specific capacity. For example, the Fort Calhoun plant in Nebraska has one reactor with the smallest generating capacity of

479 megawatts (MW). If the Fort Calhoun reactor operates at full capacity of 479 megawatts (MW) for 24 hours, it will generate 11,496 megawatt-hours (MWh) of power. Most power plants do not operate at full capacity every hour of every day of the year.

Constructing a modern nuclear power plant has a high cost, mainly due to the enormous range of safety features needed to protect against various possible mishaps. Every nuclear plant is required to have an elaborate safety system to protect against the most serious potential problem of all: the loss of coolant. This would result in the reactor core melting down and releasing radioactive material to the rest of the power plant. This must be avoided at all costs.

There are debates about the safety of nuclear power. Although nuclear energy is dangerous, several government agencies create and implement procedures to ensure the safety of people and the power plants. Still, unforeseen accidents can occur, such as the nuclear disaster in Fukushima, Japan, in spite of all the safety systems developed by nuclear engineers. The general public has long had serious concerns about the use of such plants as sources of electricity. The Fukushima event was caused by a 9.2 earthquake, which caused a tsunami that disabled the power supply and cooling of three Fukushima Daiichi reactors, causing a nuclear accident on March 11, 2011. The concern about nuclear power plants and the public fear of the technology might have arisen due to the world's first exposure to nuclear power: atomic bomb blasts that began in the 1940s.

One of the most troubling issues for nuclear power plants is waste management. After a time, the fuel rods in a reactor can no longer sustain a chain reaction and must be removed. These rods are highly radioactive and pose a threat to human life and the environment. Techniques must be developed for the destruction and/or storage of these wastes. At the moment, the U.S. government has decided to construct a huge crypt in Yucca Mountain in Nevada for the burial of high-level waste. This is only a temporary solution and needs to be improved.

Still, nuclear power plants play a vital role in energy generation. While they may be dangerous, several safety procedures are put in place, and the amount of clean energy they produce is what makes nuclear

energy so rewarding compared to other clean energy options. Scientists and nonscientists alike express hope that fusion reactions can someday be harnessed as a source of energy for everyday needs. This, however, has been much less successful compared to fission power plants.

Peg A. Lamphier

See also Solar Energy; Wind Energy; *Vol. 2, Sec. 3:* Atomic Bombs/Nuclear Weapons; Manhattan Project

Further Reading

Ferguson, Charles D. 2001. *Nuclear Energy: What Everyone Needs to Know*. New York: Oxford University Press.

Holgate, Laura. 2007. *Nuclear Security Culture: From National Best Practices to International Standards*. Washington, D.C.: ISO Press.

Saghafi, Mahdi, and Mohammad B. Ghofrani. 2016. “Accident Management Support Tools in Nuclear Power Plants: A Post-Fukushima Review.” *Progress in Nuclear Energy* 92 (September): 1–14.

Open-Source Software

Open-source software (OSS) is software with source code that any person can inspect, modify, and enhance for free. “Source code” is the part of software that most computer users don’t ever see; it’s the code that computer programmers write and can then manipulate to change how programs and applications work.

By design, open-source software licenses promote collaboration and sharing because they permit many people to view the code, copy it, learn from it, alter it, or share it. They encourage computer programmers to access, view, and modify open-source software whenever they like, as long as they let others do the same with their work when they share it. In general, open-source licenses grant computer users permission to use open-source software for any purpose they wish. Some open-source licenses stipulate that anyone who releases a modified open-source program must also release the source-code for that program alongside it.

In contrast, some other software has source code that only the person, team, or organization who

created it—and maintains exclusive control over it—can modify. This is “closed source” software, and it includes software such as Microsoft Office and Adobe Photoshop.

Many users prefer open-source software to closed-source software for a number of reasons. First, programmers have more control over open-source software. They can examine the code to make sure it’s not doing anything they do not want it to do, and they can change parts of it that they don’t like. Users who aren’t programmers also benefit from open-source software, because they can use it for any purpose they wish, unconstrained by the developer’s intentions. And it is often free to use.

Second, people who are interested in programming like open-source software because it trains them and helps them become better programmers. Because open source code is publicly accessible, students can easily study it as they learn to make better software. Students can also share their work with others, inviting comment and critique as they develop their skills. When people discover mistakes in programs’ source code, they can share those mistakes with others to help them avoid making the same mistakes themselves.

The third reason that people prefer open-source software is security. Because anyone can view and modify it, someone might spot and correct errors or omissions that a program’s original authors might have missed. And because so many programmers can work on a piece of open-source software without asking for permission from original authors, they can fix, update, and upgrade it more quickly than they can closed-source software.

Last, open-source software is stable. Users often prefer it to closed-source software for important, long-term projects. Because programmers publicly distribute the source code for open-source software, users relying on it for critical tasks can be sure their tools will not disappear or fall into disrepair if their original creators stop working on them. Additionally, open-source software tends to both incorporate and operate according to knowable standards.

While most of the Internet was born and has grown thanks to Linux open-source software, technology giants such as Google, Apple, and Facebook have embraced the open-source movement. In September

2015, Google made TensorFlow, the artificial intelligence (AI) software powering its search engines, available to the public to play with and improve. In December 2015, Apple made Swift—its own coding language—open source too. Facebook has now open-sourced almost 400 projects and has hundreds of thousands of followers on GitHub. All of these reflect a fundamental shift: to the acknowledgment of a more decentralized model of development for software.

As the digital world grows more complex, it becomes more difficult to manipulate the mountains of data and tasks. Open-source software proves to be an efficient solution by making its source code available to others so that it is developed, tested, or improved through public collaboration and distributed with the idea that it must be shared with others, ensuring an open future collaboration.

Mei B. Klein

See also Gates, Bill; Jobs, Steve; Personal Computer (PC); *Vol. 3, Sec. 3*: Linux

Further Reading

Fitzgerald, Brian, Jay P. Kesan, Barbara Russo, Maha Shaikh, and Giancarlo Succi. 2011. *Adopting Open Source Software: A Practical Guide*. Boston: MIT Press.

Rosen, Lawrence E. 2004. *Open Source Licensing: Software Freedom and Intellectual Property Law*. Upper Saddle River, NJ: Prentice Hall.

Perlman, Radia (1951–)

Radia Perlman is an engineer and mathematician who invented Spanning Tree Protocol, or STP. Spanning Tree Protocol solved an information-routing problem that was integral to the foundations of the Internet. For her invention, Perlman became known as the “Mother of the Internet.”

Born in 1952 in Virginia, Perlman grew up in New Jersey. While studying at the Massachusetts Institute of Technology, she undertook an undergraduate research opportunity with the LOGO Lab called Toddler’s Own Recursive Turtle Interpreter System (“TORTIS”). The project enabled children as young as

three and a half years old to program educational robots and made Perlman a pioneer of teaching young children computer programming.

After obtaining her master’s degree in mathematics in 1976, Perlman accepted a position with Bolt Beranek and Newman in government contracting to develop software for network equipment. Her work on network routing attracted the attention of the Digital Equipment Corporation (DEC), which she joined in 1980. Perlman was tasked with working on ways for computers to reliably share information. Her research led to the invention of Spanning Tree Protocol in 1985, which allows a network to deliver data reliably by making it possible to design the network with redundant links. This method enables automatic backup paths if an active link fails, and it disables the links that are not part of the tree—thereby creating a single, active path between any pair of network nodes. The first version of Spanning Tree Protocol was based on Perlman’s algorithm, called DEC STP, and subsequent versions have incorporated various extensions. Spanning Tree Protocol transformed the original limited-scalability, single-wire CSMA/CD into a protocol that could handle large clouds. As a result, the basic traffic rules for large networks, like the Internet, were laid. The concept was adopted by the IEEE as a standard for bridge technology and remains in place to this day.

Perlman obtained her doctorate in computer science from the Massachusetts Institute of Technology in 1988, with a thesis on routing in environments where malicious network failures are present. Her thesis served as the basis for much of the work that now exists in the field. She also holds an honorary doctorate from the Royal Institute of Technology. In 1997, she joined Sun Microsystems, where in 2007, she was given the title of distinguished engineer. She continues her work in network security today, working to make STP more robust and stable while establishing optimal paths between points as part of the transparent interconnection of lots of links (TRILL) project. Perlman has also served as a professor at Harvard University, the University of Washington, and the Massachusetts Institute of Technology. She has authored numerous textbooks on networking and network security and holds more than 100 issued patents. She has also

received numerous awards, including the first-ever Anita Borg Institute Women of Vision Award for Innovation (2005), the USENIX Lifetime Achievement Award (2006), and the SIGCOMM Award (2010). She was inducted into the Internet Hall of Fame in 2014 and the National Inventors Hall of Fame in 2016.

Tiffany Rhoades

See also *Vol. 1, Sec. 3*: Mitchell, Maria; *Vol. 2, Sec. 1*: Roebling, Emily; *Vol. 2, Sec. 2*: Cannon, Annie Jump; *Vol. 2, Sec. 3*: Clarke, Edith; *Vol. 3, Sec. 1*: Brown, Marie Van Brittan; Morgan, Mary Sherman

Further Reading

Morgado, Leonel, et al. 2006. “Radia Perlman—A Pioneer of Young Children Computer Programming.” *Current Developments in Technology-Assisted Education* (January): 1903–7.

Personal Computer (PC)

While engineers might look to an earlier date for the birth of the personal computer, for business historians, it was 1977 that launched its mass merchandising. Today, the year is known as the “1977 Trinity” of Apple, Radio Shack, and Commodore computers. This trinity brought monitors, keyboards, and tape (as in the standard cassette tape of the period) memory to the previous mathematical boxes and video games. In 1977, Radio Shack offered the first mass-marketed PC in the TRS-80, with prices starting at \$600. Radio Shack proved that the personal computer would be a mainstream consumer product. The Commodore PET was also released in 1977 with a price of \$800; and while it had limited success, it would set the stage for the highest-selling sales model ever, the Commodore 60, a few years later. Commodore would be the first to use major retail store outlets such as Kmart. Similarly, the limited release of the Apple II would herald the beginning of the personal-computing giant Apple Inc. The Apple II had a price between \$1,200 and \$2,600, depending on its memory size. Apple chose to develop its own retail outlets. The TRS-80 sold through Radio Shack would set the business sales model for many companies, while the Apple II would set the consumer

design model for mass merchandising the personal computer.

The commercial history of the personal computer can be traced to the 1975 release of the Altair computer kit in *Popular Electronics*. The Altair kit cost around \$400 and was little more than a box with switches. While the Altair with the Intel 8080 chip delivered little, it did spark a burst of creativity in the marketplace. One incubator of this creativity was the Homebrew Computer Club near Stanford University.

Apple founders Steve Jobs and Steve Wozniak, future founders of Apple Computer, were members of this hobbyist group. Wozniak tested out his ideas for the Apple computer at the Homebrew Club. Jobs, his partner, injected the business and marketing assets into personal computer design. Wozniak worked hard to reduce the chips needed for a personal computer from over 50 to just 5. The Apple II had a monitor for graphical display, which was lacking in the Altair. Out of the trinity of personal computers in 1977, the Apple II was the first to use a color monitor. From the start, Jobs incorporated his vision of “user friendliness” that would come to characterize Apple products. The team of Jobs and Wozniak proved the perfect balance of technology and business sense. Apple II was the best customer-oriented product with a ready-to-use computer out of the box. Apple II sales started off slow, lacking the mass marketing of larger companies, but proved the impact of word of mouth in the consumer base among hobbyists and gamers.

The Radio Shack TSR-80 was the first personal computer produced by a major company, which was Tandy Corporation, owner of 3,000 retail stores and a national mailing list. Tandy used its engineering staff to hold down costs, realizing that the market would be price sensitive. Tandy Corporation tried to move beyond electronics hobbyists by offering software applications on cassette tape. It gave blackjack and backgammon software away for free and offered additional applications, such as for personal finance and small business payroll management. Tandy’s marketing had identified a market potential of the personal computer in small businesses. Tandy’s marketing pushed sales over 10,000 in the first two months.

The Commodore PET (Personal Electronic Transactor) was aimed at educators and calculator users of

the time. Commodore's experience was in calculators. In the early 1970s, there was a brisk market in programmable calculators sold by Texas Instruments, Hewlett-Packard, and Commodore. These programmable calculators sold for around \$800 but were popular with engineers and educators. The PET's price of \$800 made it very competitive in the calculator market. It had a tough, single-unit design (monitor, processor, and keyboard) that made it popular with schools, in which Commodore's marketing group had inroads. The calculator-based keyboard, however, limited its general popularity. The Commodore PET never matched the sales of the TRS-80 or Apple II, but it did set the platform for the Commodore 64, which addressed its market shortcomings. In the 1980s, the Commodore 64 sold through outlets like Kmart and made it the Model T of personal computers—and the world's bestselling personal computer model of all time. Commodore proved that the personal computer could be a mass-produced consumer product.

The trinity of personal computers with their various business models would evolve into a huge consumer market combining hobbyists, gamers, engineers, small businesspeople, scientists, and educators. Two developments during the next two years would expand the market and sales of the personal computer. The first was the use of floppy drives versus the slow standard cassette drives. IBM had invented floppy drives in 1967, and hobbyists were using them with their Altairs. A floppy drive could read 100,000 bits per second versus a mere 1,000 bits per second for a cassette drive. Floppy drives allowed a market to develop in software applications. Cassette storage had limited the personal computer to small, simple programs. The next development would be to release a breakthrough application. The trinity of personal computers still attracted people who were proficient in writing programs.

The limited applications available for small businesses and professionals were restricting the market. Interestingly, software became a separate industry as initially, companies like Apple focused on hardware. Still, to a large degree, the lack of software was the limiting factor in early hardware sales. The breakthrough application was *VisiCalc*, a spreadsheet

application for accounting and financial calculations. Daniel Bricklin and Robert Frankston developed it on an Apple II computer. They began selling the application for \$200, and the software became the driving force for Apple sales, which boomed. The company's stock went public in December 1980. Still, the major adoption of personal computers in the business world would await the introduction of the IBM personal computer in early 1982.

Quentin R. Skrabec

See also Apple; Apple II; Artificial Intelligence (AI); Computer/Information Technology; Dell, Michael “Saul”; Floppy Disk; IBM Personal Computer; Internet; Jobs, Steve; Kare, Susan; Wozniak, Steve; *Vol. 3, Sec. 1*: Commodore 64; Fortran; IBM 360 Computer; Integrated Circuit; Intel Corporation; Single-Chip Microprocessor; Universal Automatic Computer (UNIVAC); Xerox Corporation; *Vol. 3, Sec. 3*: Facebook; iPod; Joystick/Flight Simulator; Linux; Smartphone and 3G Network; TOR (The Onion Router); Video Game; Virtual Reality (VR); YouTube

Further Reading

- Ceruzzi, Paul E. 2003. *A History of Modern Computing*. Cambridge, MA: MIT Press.
- Wozniak, Steve. 2006. *iWoz: Computer Geek to Cult Icon: How I Invented the Personal Computer, Co-Founded Apple, and Had Fun Doing It*. New York: W. W. Norton.

Ride, Sally (1951–2012)

Physicist Sally Kristen Ride was the first American female astronaut to go to space. She was also the first lesbian astronaut and held the record for being the youngest astronaut from the United States to have been launched into space. She spent her last years encouraging children, especially girls, to do well in math and sciences by creating Sally Ride Science.

Ride was born in Los Angeles, California, on May 26, 1951. She was a good student overall but liked science best. Ride was also an exceptional athlete and excelled at tennis; she subsequently was a nationally



Sally Ride, seen here on Day 6 of her 1983 *Challenger* mission, was the United States' first woman in space. (National Archives)

ranked junior tennis player and earned a tennis scholarship to the Westlake School for Girls. She attended Swarthmore College and the University of California, Los Angeles before graduating from Stanford University with a bachelor of arts in English and a bachelor of science in physics in 1973. Ride continued her studies at Stanford and earned a master of science in 1975 and a doctorate in 1978, both in physics.

Like many young Americans, Ride was fascinated with space exploration, but in the 1970s, the National Aeronautics and Space Administration (NASA) only hired male ex-military test pilots for its astronaut program. But in 1978, Ride saw a NASA recruitment

advertisement in the Stanford University newspaper that asked for scientists for the Space Shuttle program. The announcement did not exclude women. Ride applied for a position as a NASA scientist and was among 35 people out of 8,000 applicants to be chosen for the program.

Ride trained for over a year and then qualified to be a mission specialist for the space shuttle flight crews. She served on the ground crew for two shuttle launches and helped design the shuttle's robotic arm. In 1982, she married Steven Hawley, who was also a NASA astronaut. The couple divorced five years later. In 1983, on the *Challenger's* second launch, Ride became the

first American woman in space (two Soviet women preceded Ride). Her first mission was the STS-7 mission for satellite deployment and microgravity research. She was launched into space in 1984 for a second time on the space shuttle *Challenger* for the STS-41-G mission for satellite deployment and radar imaging. Ride orbited Earth for approximately 344 hours total. In 1986 when the *Challenger* exploded in midair, killing all the astronauts aboard, Ride's next mission, which was supposed to take place aboard the *Challenger*, was canceled, and she was called to serve as part of the presidential commission to investigate the accident.

After the investigation, Ride worked at NASA for a few more years until she became a professor of physics at the University of California, San Diego in 1989. That year, Ride also became the director of the California Space Institute and then founded Sally Ride Science in 2001 to motivate girls to pursue careers in STEM (science, technology, engineering, and mathematics) programs with business and life partner Tam O'Shaughnessy. The company's mission is to create science projects aimed at attracting children and teenagers, particularly girls, to science. Ride was also the company's president and CEO and positively influenced the education system with her advocacy of science to young girls. Using her English degree to further educate the public, Ride wrote books with O'Shaughnessy about science and space exploration, including six well-regarded children's books.

A few years later in 2003, Ride was appointed to be a member for the space shuttle *Columbia* investigation team when it disintegrated upon reentry into Earth's atmosphere, killing everyone on board. She was the only person to have served on both committees for the disasters of the *Challenger* and *Columbia* space shuttles.

Ride received many awards, including the Von Braun Award, the NASA Space Flight Medal (twice), and the General James E. Hill Lifetime Space Achievement Award, among others. Ride was diagnosed with pancreatic cancer in 2011 and died in 2012. She continues to receive awards and honors even after her death. In 2013, President Barack Obama presented O'Shaughnessy with the Presidential Medal of Freedom (the highest civilian award in the United States), who accepted it on behalf of her partner, Ride.

Mariana Magaña

See also Vol. 3, Sec. 1: Hopper, Grace; Vol. 3, Sec. 3: Jemison, Mae

Further Reading

Marck, Bernard. 2013. *Women Aviators: From Amelia Earhart to Sally Ride, Making History in Air and Space*. New York: Flammarion.

Sherr, Lynn. 2014. *Sally Ride: America's First Woman in Space*. New York: Simon & Schuster.

Ritchie, Dennis (1941–2011)

Dennis Ritchie was a very accomplished computer scientist who considered himself not smart enough for physics and complex algorithms. Ritchie's most notable contribution to the world of computing was the creation of the C programming language. He built it by adding "types" and other features onto the B programming language between 1969 and 1973, much like what Bjarne Stroustrup would do with the C++ programming language in the coming years. Ritchie developed his C language in parallel with the Unix operating system, which he aided Ken Thompson in building during their employment at Bell Labs in Murray Hill, New Jersey. The C programming language became a far greater success than he had anticipated. Ritchie owes much of the language's success to Thompson, who had developed the B programming language, and Martin Richard, who had developed B's predecessor BCLP.

Born in Bronxville, New York, on September 9, 1941, Dennis Ritchie was the son of Alistair E. Ritchie, who himself had coauthored a highly influential book with W. Keister and S. Washburn called *The Design of Switching Circuits* focusing on switching theory and logic design before the advent of the transistor. Ritchie started working at Bell Labs, following in his father's footsteps in 1967, and soon thereafter began contributing to the Multics (Multiplexed Information and Computing Service) project, a collaborative effort between Bell Labs, the Massachusetts Institute of Technology, and General Electric to create a time-shared operating system.

Ritchie began development on the C programming language in 1969, and its development peaked

in 1972 before he completed the base language in 1973. His original desire was to create a programming language that incorporated many of the advanced features from the Multics (Multiplexed Information and Computing Service) operating system. These features were to include an explicit notion of a process as a locus of control, a tree-structured file system, a command interpreter as a user-level program, simple representation of text files, and generalized access to devices. Even more features were to be added in 1977 and 1979 when the Unix operating system began flexing its ability to be highly portable, but it was not until the mid-1980s that the language would be standardized by the American National Standards Institute X3J11 committee.

The C programming language was originally designed to be the foundation for the Unix operating system but has since grown to be the most widely used programming language in every industry today and can be used with most platforms. Ritchie, along with Brian Kernighan, coauthored and published the second edition of *The C Programming Language* in 1988 under Prentice Hall Inc. The book has seen great success and countless translations, and it is still one of the most popular programming references today. Ritchie had other interests in computer science as well, including cryptography, which he spent some time researching and discussing with the National Security Agency, and computer games, which he collaborated on with Thompson.

Ritchie had a very diverse life that included many distinct interests and life experiences, including a brief truck-driving career where he was quickly promoted to safety director for the Swift Transportation company. He also worked as a driver hauling NASCAR race cars to and from races for the Roush Racing and Valvoline team. After spending some time on his high school audio and video squad, Ritchie delved into a

small side career as a recording engineer for up-and-coming country and western singers in Nashville, Tennessee. Among these artists was the prominent Jill Anne Curington as well as some less lucrative artists from Brazil. These alternative careers were short-lived compared to his lifelong career in computer science.

Ritchie was the recipient of numerous prestigious awards, including the Association for Computing Machinery's award for Outstanding Paper of 1974 in systems and languages, the Institute of Electrical and Electronics Engineers Emmanuel R. Piore Award in 1982, a Bell Laboratories Fellowship along with the Association for Computing Machinery's Turing Award and Software Systems Award in 1983, the C & C Foundation Award of NEC in 1989, and the Institute of Electrical and Electronics Engineers Hamming Medal in 1990. In 1988, Ritchie was elected to the U.S. Academy of Engineering, and 11 years later, in April 1999, Ritchie was presented the U.S. National Medal of Technology by president Bill Clinton. Dennis Ritchie passed away in early October 2011.

Jeremy C. Kleve

See also Vol. 2, Sec. 2: Bell Telephone Laboratories; Vol. 2, Sec. 3: MIT Radiation Laboratory; Vol. 3, Sec. 3: Negroponte, Nicholas

Further Reading

Kernighan, Brian W., and Dennis M. Ritchie. 1988. *The C Programming Language*. Englewood Cliffs, NJ: Prentice Hall.

Ritchie, Dennis. 1993. "The Development of the C Language." *Tech.* April. <https://www.bell-labs.com/usr/dmr/www/chist.pdf>, accessed August 31, 2018.

Ritchie, Dennis. 2011. "Dennis M. Ritchie." October. <https://www.bell-labs.com/usr/dmr/www/bigbio1st.html>, accessed August 31, 2018.

Primary Document: Abstract for "The Development of the C Language" by Dennis Ritchie (1993)

In this abstract of his paper on "The Development of the C Language," Dennis Ritchie discusses the history of the development of the C programming

language. The full paper touches on the language's predecessors such as B and BCPL and the origin of the language in terms of what he was trying to

accomplish. Much of the focus is on the problems that occurred during its creation, how he solved these problems, and what became of the C programming language after its inception. He also touches on the C++ language, C's successor, and the standardization of C as the most commonly used programming language, which he credits to the success and widespread usage of the Unix operating system developed by Ken Thompson and himself.

The Development of the C Language by Dennis M. Ritchie

Bell Labs/Lucent Technologies

Murray Hill, NJ 07974 USA

dmr@bell-labs.com

ABSTRACT

History: the setting

The late 1960s were a turbulent era for computer systems research at Bell Telephone Laboratories. The company was pulling out of the Multics project [Organick 75], which had started as a joint venture of MIT, General Electric, and Bell Labs; by 1969, Bell Labs management, and even the researchers, came to believe that the promises of Multics could be fulfilled only too late and too expensively. Even before the GE-645 Multics machine was removed from the premises, an informal group, led primarily by Ken Thompson, had begun investigating alternatives.

Thompson wanted to create a comfortable computing environment constructed according to his own design, using whatever means were available. His plans, it is evident in retrospect, incorporated many of the innovative aspects of Multics, including an explicit notion of a process as a locus of control, a tree-structured file system, a command interpreter as user-level program, simple representation of text files, and generalized access to devices. They excluded others, such as unified access to memory and to files. At the start, moreover, he and the rest of us deferred another pioneering (though not original) element of Multics, namely writing almost exclusively in a higher-level language. PL/I, the implementation language of Multics, was not much to our tastes, but we were also using other languages, including BCPL, and we regretted losing the

advantages of writing programs in a language above the level of assembler, such as ease of writing and clarity of understanding. At the time we did not put much weight on portability; interest in this arose later.

Thompson was faced with a hardware environment cramped and spartan even for the time: the DEC PDP-7 on which he started in 1968 was a machine with 8K 18-bit words of memory and no software useful to him. While wanting to use a higher-level language, he wrote the original Unix system in PDP-7 assembler. At the start, he did not even program on the PDP-7 itself, but instead used a set of macros for the GEMAP assembler on a GE-635 machine. A postprocessor generated a paper tape readable by the PDP-7.

These tapes were carried from the GE machine to the PDP-7 for testing until a primitive Unix kernel, an editor, an assembler, a simple shell (command interpreter), and a few utilities (like the Unix rm, cat, cp commands) were completed. After this point, the operating system was self-supporting: programs could be written and tested without resort to paper tape, and development continued on the PDP-7 itself.

Thompson's PDP-7 assembler outdid even DEC's in simplicity; it evaluated expressions and emitted the corresponding bits. There were no libraries, no loader or link editor: the entire source of a program was presented to the assembler, and the output file with a fixed name that emerged was directly executable. (This name, a.out, explains a bit of Unix etymology; it is the output of the assembler. Even after the system gained a linker and a means of specifying another name explicitly, it was retained as the default executable result of a compilation.) Not long after Unix first ran on the PDP-7, in 1969, Doug McIlroy created the new system's first higher-level language: an implementation of McClure's TMG [McClure 65]. TMG is a language for writing compilers (more generally, TransMoGrifiers) in a top-down, recursive-descent style that combines context-free syntax notation with procedural elements. McIlroy and Bob Morris had used TMG to write the early PL/I compiler for Multics.

Challenged by McIlroy's feat in reproducing TMG, Thompson decided that Unix possibly it had not even been named yet needed a system programming

language. After a rapidly scuttled attempt at Fortran, he created instead a language of his own, which he called B. B can be thought of as C without types; more accurately, it is BCPL squeezed into 8K bytes of memory and filtered through Thompson's brain. Its name most probably represents a contraction of BCPL, though an alternate theory holds that it derives from Bon [Thompson 69], an unrelated language

created by Thompson during the Multics days. Bon in turn was named either after his wife Bonnie, or (according to an encyclopedia quotation in its manual), after a religion whose rituals involve the murmuring of magic formulas.

Source: Ritchie, Dennis M. "Abstract." Available at: Bell Labs: <https://www.bell-labs.com/usr/dmr/www/chist.pdf>.

Robotic Surgery

Robotic surgery is a relatively new area of technology. The earliest known procedure involving robotic assistance was in 1985, where the PUMA 560, a surgical arm, assisted in a neurosurgical biopsy. Since then, technology has come a long way. 1990 marked the first time a system, created by AESOP, of this type was approved by the U.S. Food and Drug Administration for use, but it was not until 2000 that the FDA approved the first surgery system as we know it today. The da Vinci Surgical System, made by the current powerhouse of the industry, Intuitive Surgical, allows for extreme precision, reduced chance of infection, and reduced scarring. Robotic surgery has been praised for its smooth and fluid movements, which exceed those of even the most precise human being.

Robotic surgery is not without controversy. As with any new technology, it is expensive. With robots ranging in price upward of \$1 million, procedures that use robotic assistance often cost more than those completed by human physicians. Another critique of adopting robotic assistants as the norm is that it requires additional surgical training, which puts an even greater burden on surgeons who are already bogged down by years of schooling. Additionally, since the only way to learn these procedures is hands on, and the number of robotic surgery devices is limited, operating rooms often become backed up with procedures. It can take 12 to 18 operations before a surgeon adapts to the robotic surgical assistant. The American Congress of Obstetricians and Gynecologists opposed robotic surgery, as it did not feel there was yet a significant-enough depth of evidence that

the pros of reduced recovery time outweighed the extra burden taken on by hospitals and patients alike due to the high costs.

However, if the burdens of cost can be put aside, examples of the advancements in robotic surgery bring hope to those who wish to maintain a normal life despite the need for extreme surgeries. In the short term, some patients have been able to leave the hospital just days after major surgery due to the lack of invasiveness on the part of the robots. The lack of deep incisions at the hands of a surgeon means that patients are less likely to reopen a wound soon after an operation, and they can return to daily activity more easily. Additionally, while it is still disputed, robotic-assisted surgery's greater precision appears to lower mortality rates of procedures in both the short term and the long term.

Cassady O'Reilly-Hahn

See also Vol. 2, Sec. 1: Edison, Thomas

Further Reading

- Chen, Michelle M., Sanziana A. Roman, Dennis H. Kraus, Julie A. Sosa, and Benjamin L. Judson. 2014. "Transoral Robotic Surgery." *Otolaryngology—Head and Neck Surgery* 150, no. 6: 968–75.
- Lee, Jason Y., Phillip Muchsavage, Chandru P. Sundaram, and Elspeth M. McDougall. 2011. "Best Practices for Robotic Surgery Training and Credentialing." *The Journal of Urology* 185, no. 4: 1191.
- Weissman, Joel S., and Michael Zinner. 2013. "Comparative Effectiveness Research on Robotic Surgery." *JAMA, the Journal of the American Medical Association* 309, no. 7: 721.

Primary Document: Letter from Elizabeth A. Kage, Acting District Director of the FDA, to Gary S. Guthart, President of Intuitive Surgical Inc., on the Regulation of Robotic Surgery (2013)

This letter between Elizabeth A. Kage, acting district director of the FDA, and Gary S. Guthart, president of Intuitive Surgical Inc., reflects the ongoing regulations of robotic surgery so that it meets acceptable standards for the maintenance of human life. Intuitive, the company largely responsible for the development and production of the “da Vinci” system, the premier surgical assistant device, was found to have mislabeled devices, and it was told to create a report on why this happened. This is important historically for understanding the development and restriction on the usage of these devices while they are being sold for profit by businesses that are responsible for the health of the general population.

Mr. Guthart

During an inspection of your facility located at 1266 Kifer Road, Sunnyvale, CA between April 1, 2013 and May 30, 2013, and investigator from the United States Food and Drug Administration (FDA) determined that your firm manufactures computer controlled endoscopic surgical systems and associated accessories. Under section 201(h) of the Federal Food, Drug, and Cosmetic Act (the Act), 21 U.S.C. § 321(h), these products are devices because they are intended for use in the diagnosis of disease or other conditions or in the cure, mitigation, treatment, or prevention of disease, or to affect the structure or any function of the body.

The inspection revealed that your da Vinci System IS1000, da Vinci System IS1200, da Vinci System IS2000, da Vinci System IS3000, Tip Cover Accessory, and Cannula 8mm Regular are misbranded devices under section 502(t)(2) of the Act, 21 U.S.C. 352(t)(2), in that you failed or refused to furnish material or information respecting the device that is required by or under section 519 of the Act, 21 U.S.C. § 360i, and 21 CFR 806-Medical Devices; Reports of Corrections and Removals regulation. Significant deviations include, but are not limited to the following:

Failure to submit a written report to FDA within 10 working days of any correction or removal of a

device if the correction or removal was initiated to reduce the risk to health posed by the device or to remedy a violation of the act which may present a risk to health as required by 21 CFR 806.10(b).

Examples of these failures include but are not limited to the following:

1. In October 2011, Intuitive Surgical, Inc. initiated a field correction by sending letters to da Vinci Surgical System clients with suggestions and recommendations for the proper use of the Tip Cover Accessory and for the correct generators that should be used with monopolar instruments. This correction was in response to complaints and medical device reports (MDRs) for arcing through damaged tip covers that caused patient injuries. Though the field action was undertaken to reduce a risk to health posed by the device, you failed to report the field action to the FDA as required. Your report of this recall on April 19, 2013 has been classified by FDA as a Class II recall, Z-1425-2013.
2. In October 2011, Intuitive Surgical, Inc. initiated a separate field correction by sending letters to da Vinci Surgical System clients to notify them that the da Vinci Surgical Systems promoted for thyroidectomy indications is not cleared for that use. You are aware of complaints and MDRs related to thyroidectomies performed with the da Vinci Surgical System. Though the field action was undertaken to reduce a risk to health posed by the device, you failed to report the field action to the FDA as required. Your report of this recall on April 19, 2013 has been classified by FDA as a Class II recall, Z-1426-2013.
3. In October 2011, intuitive Surgical, Inc. initiated a separate field correction by sending letters to da Vinci Surgical System clients with information for inspecting the instrument cannulas, proper flushing of the instruments, and proper transportation of the da Vinci Surgical System between buildings. Though the field action was undertaken to reduce a risk to health posed by the device, you failed to report the field action to

the FDA as required. Your report of this recall on April 19, 2013 has been classified by FDA as a Class II recall, Z-1428-2013.

4. In January 2013, Intuitive Surgical, Inc. initiated a field correction by sending letters and replacement user manual addendum titled “da Vinci, da Vinci S, and da Vinci Si Surgical Systems User Manual Addendum for Transoral Surgery (TORS) P/N 552003-02 Rev.B 2012.09” to da Vinci Surgical System clients. The replacement addendum includes changes to the types of patients and conditions for which da Vinci TORS is indicated, such as warning against use in pediatric patients. Though the field action was undertaken to reduce a risk to health posed by the device, you failed to report the field action to the FDA as required. Your report of this recall on April 19, 2013 has been classified by FDA as a Class II recall, Z-1424-2013.

We have reviewed your response dated June 7, 2013 and find it incomplete and inadequate. Your standard operating procedure titled Field Actions, document 853012, revision T indicates that all corrections, removals, and labeling reiterations will be reviewed with the local district recall coordinator or 3rd party expert. We are unable to assess the adequacy of this change as we cannot evaluate the extent of the information that will be submitted to the local FDA recall coordinator. Nor can we assess how you will implement this new requirement in your SOP.

In addition, Section 6.3 of your work instruction titled Regulatory Notifications, document 859179, revision F intended to be used after a determination is made to file a field correction/removal indicates that Class I and Class II actions are to be reported, and Class III actions will be directed to the Head of Regulatory Affairs. This work instruction appears to contradict your Field Actions SOP, document 853012, which indicates that all corrections, removals, and labeling reiterations will be reviewed with the local district recall coordinator or 3rd party expert.

The FDA has previously informed you of your firm’s correction and removal violations in an untitled letter dated February 19, 2008, and FDA 483 Inspectional Observations issued on December 20, 2002.

A follow-up inspection will be required to assure that your corrections and/or corrective actions are adequate and properly implemented.

The inspection also revealed that your da Vinci System IS1000, da Vinci System IS1200, da Vinci System IS2000, da Vinci System IS3000, Tip Cover Accessory, and Cannula 8mm Regular are adulterated devices under section 501(h) of the Act, 21 U.S.C. 351(h), in that the methods used in, or the facilities or controls used for its manufacture, packing, storage, or installation are not in conformity with the Current Good Manufacturing Practice (CGMP) requirements for devices which are set forth in the Quality System regulation, as specified in Title 21, Code of Federal Regulations (CFR), Part 820. Significant deviations include, but are not limited to the following:

Design input requirements were not adequately documented as required by 21 CFR 820.30(c). Specifically, you informed our investigator that you are aware of patient injuries associated with intraoperative cleaning of energized instruments such as the Monopolar Curved Scissors and Fenestrated Bipolar Scissors as evidenced by at least (b)(4) complaints and 82 MDRs during calendar years 2010 and 2011, and 15% of the MDRs reviewed by our investigator. You also informed our investigator that you are aware that cleaning instruments inside patients during surgery is a common practice and have included a label warning in the Instructions-for-Use (IFU) against the practice. When our investigator asked you to provide the design input documentation and design resolution of this known user need you failed to provide the requested documentation.

We have received your response dated June 7, 2013 and find your response to this observation inadequate. Your modification to section 8.1 of document number 823033, revision H in that you are concluding that the IFU adequately consider the known intraoperative cleaning of instruments and the associated risks without going through your design control processes. Your response is also inadequate in that you do not provide a response to the root cause of this critical missing design input in your design documentation.

Your firm should take prompt action to correct the violations addressed in this letter. Failure to promptly correct these violations may result in regulatory

action being initiated by the FDA without further notice. These actions include, but are not limited to, seizure, injunction, and/or civil money penalties. Also, federal agencies may be advised of the issuance of Warning Letters about devices so that they may take this information into account when considering the awarding of contracts.

Please notify this office in writing within fifteen business days from the date you receive this letter of the specific steps your firm has taken to correct the noted violations, as well as an explanation of how your firm plans to prevent these violations, or similar violations, from occurring again. Include documentation of the corrections and/or corrective actions (including any systemic corrective actions) that your firm has taken. If your firm's planned corrections and/or corrective actions will occur over time, please include a timetable for implementation of those activities. If corrections and/or corrective actions cannot be completed within fifteen business days, state the reason for the delay and the time within which these activities will be completed. Your firm's response should be comprehensive and address all violations included in this Warning Letter.

Your firm's response should be sent to: Lawton W. Lum, Director of Compliance, 1431 Harbor Bay

Parkway, Alameda, CA 94502. Refer to the Unique Identification Number 406661 when replying. If you have any questions about the contents of this letter, please contact: Compliance Officer Sergio Chavez at 510-337-6886.

Finally, you should know that this letter is not intended to be an all-inclusive list of the violations at your firm's facility. It is your firm's responsibility to ensure compliance with applicable laws and regulations administered by FDA. The specific violations noted in this letter and in the Inspectional Observations, FDA 483, issued at the close of the inspection may be symptomatic of serious problems in your firm's manufacturing and quality management systems. Your firm should investigate and determine the causes of the violations, and take prompt actions to correct the violations and bring the products into compliance.

Sincerely,
/S/
Elizabeth A. Kage
Acting District Director

Source: U.S. Food and Drug Administration (FDA). Available at: <http://www.fda.gov/ICECI/EnforcementActions/WarningLetters/2013/ucm363260.htm>.

Satellite Radio

Satellite radios are radios that receive signals from satellites that move in space at the same speed as the rotation of the earth. These satellites are stationary in space and follow the earth's orbit, so satellite radios in homes have a stronger signal compared to radios serviced by terrestrial antennas. Satellite signals are broadcast nationwide as signals are sent from Earth to the satellite and then transmitted back to Earth, with much wider coverage than terrestrial radio stations. Terrestrial radio consists of antennas that are placed near the radio station to broadcast the signal over the air to a local area only.

In 1988, XM Satellite Radio was invented by Hugh Panero and Gary Parsons, who wanted to bring satellite and online radio broadcasts to the United States and Canada. On May 17, 1990, Martine A.

Rothblatt, Robert Briskman, and David Margolese developed Sirius Satellite Radio, which was a satellite and online radio service that operated in North America. Officially launching on September 25, 2001, it was not until July 29, 2008, that XM Satellite Radio and Sirius Satellite Radio merged to create Sirius XM Radio, as satellite radio is known today in the United States, and its affiliate, Sirius XM Canada, began its service in 2010. The Astra satellite service currently operates in Europe, with other countries' satellite services not currently operational.

The company known today as Sirius XM Radio has more than 18 million paying subscribers. They can listen to Sirius XM Radio on their phones, in their cars, or in their homes. Satellite radio uses two Boeing HS 702 communication satellites nicknamed "Rock" and "Roll," and two Boeing BSS 702 communication satellites called "Rhythm" and "Blues." These Sirius

XM Radio satellites are in a stationary orbit, or a geosynchronous orbit, that is parallel to Earth, with two of the satellites at 85 degrees west longitude, and the other two satellites at 115 degrees west longitude. The radio receivers on the ground are meant to unscramble and receive digital data to provide more than 170 radio channels for Sirius XM subscribers.

These satellite radios have become progressively more popular over the last 10 years as subscribers admire the range and different genres of uncensored content and music, like country and hip-hop, talk, comedy, and even local weather, sports, and traffic. One of the many positives that subscribers enjoy when listening to Sirius XM Radio is the lack of commercials, since subscriber fees pay for the service. While many listeners of Sirius XM Radio enjoy listening to radio in their homes, these subscribers enjoy using Sirius XM Radio in their cars because of the wide broadcast range that Sirius XM Radio provides throughout North America as they travel through different counties or states where terrestrial radio signals cannot reach.

Sarah Mae Halpern Weise

See also *Vol. 2, Sec. 2: Radio; Vol. 3, Sec. 1: Comsat/Intelsat; Satellites and Space Probes*

Further Reading

Ippolito, Louis J., Jr. 2017. *Satellite Communications Systems Engineering: Atmospheric Effects, Satellite Link Design and System Performance*. London: John Wiley & Sons.

Leinwoll, Stanley. 1979. *From Spark to Satellite: A History of Radio Communication*. New York: Scribner.

Self-Driving Cars

The concept of a self-driving car, or rather, a driverless car, dates back nearly to the inception of the car itself. Just 40 years after the car was created, drivers were already looking for avenues to get their hands off the wheel. The first instance of this came in 1925, offered by Houdina Radio Control. Houdina created the American Wonder, a car that could be controlled

through an antenna with radio waves from a short distance. At the time, it was revolutionary, despite the need for the controller to be traveling just behind the car. But it would not be long before further developments were made. In 1958, RCA had a car running along a track with electrical circuits that ordered it to accelerate, stop, and turn. At one point, in 1960, four states were eyeing construction of a highway link with this kind of circuitry.

The 1980s upped the ante with the Prometheus project, where German engineer Ernst Dickmanns worked with Mercedes-Benz to create a van that could travel at 39 miles per hour. It reacted to sensory input that was translated to commands for the program. American ingenuity entered the modern fray of the self-driving car in 1991, when legislation was passed that asked the Department of Motor Vehicles to create a roadway that was fully automatic. Due to waning funding, however, the project was canceled shortly after a 1997 demonstration in San Diego. Meanwhile, Ernst Dickmanns was furthering his development of a robotic car, helping to drive it through Paris traffic at 20 miles per hour in 1994. By 1995, the car made a trip to Copenhagen from Bavaria, traveling faster than 100 miles per hour.

At the turn of the century, the race for a self-driving car turned away from being a country-led proposition and became one for various international companies to compete for, putting companies like Ford, Mercedes-Benz, BMW, and Audi at the forefront of the picture. Famously, Audi created an autonomous vehicle capable of traversing Pike's Peak, one of the highest summits in the Rocky Mountains. Legislation in 2011 allowed access for driverless vehicles in Nevada on the open road.

Google entered the bidding around this time and began working with several car companies to produce new technology. Google's project came to fruition in 2014 after taking to several roads throughout the country as more states passed legislation allowing these cars. Google had planned to entirely remove the steering wheel and pedals from its car, which had not been done before. Google had the goal to place fully functional models in San Francisco by 2015. While self-driving cars are not available to the public yet, many companies are pressing for their implementation.

Google has aimed for a 2020 offering, while Mercedes has already added some autopilot features to its cars starting as early as 2014.

Ethical questions arise in the event of accidents with driverless cars. If someone were to unknowingly step out in front of a driverless car and was hurt, is the person or the company responsible? Critics offer the idea that a computer does not have the capacity to make an unbiased decision about human life. These questions inquire about whether it is morally acceptable to move forward with this technology.

Cassady O'Reilly-Hahn

See also *Vol. 2, Sec. 2: Automobile Technologies (Pre–World War II); Vol. 3, Sec. 1: Automotive Technologies (Post–World War II); Vol. 3, Sec. 3: Google*

Further Reading

Goodall, Noah. 2016. “Can You Program Ethics into a Self-driving Car?” *IEEE Spectrum* 53, no. 6: 28–58.

Wright, Alex. 2011. “Automotive Autonomy.” *Communications of the ACM* 54, no. 7: 16.

Zhang, Yunling, Guofeng Wang, Xingfa Gu, Shaoming Zhang, and Jianping Hu. 2015. “Real-Time Pedestrian Detection with the Videos of Car Camera.” *Advances in Mechanical Engineering*. 7, no. 12.

SEMATECH

Founded in 1987 in Austin, Texas, SEMATECH, short for “semiconductor manufacturing technology,” is a nonprofit consortium that does research for advancements in silicon chip technology and development. The company’s main objective is to procure technologies that reduce manufacturing costs while decreasing the number of defects per chip. This consortium consists of several companies working toward a common goal of producing high-quality, advanced microscopic silicon computer chips, otherwise known as silicon integrated circuits, while retaining a competitive edge as a worldwide leader and innovator in the semiconductor industry.

SEMATECH began as a partnership between the U.S. government and 14 semiconductor chip manufacturers to resolve manufacturing inefficiencies and gain

a competitive edge over Japan, who at the time dominated the industry. The consortium includes industry giants such as Intel and Texas Instruments. An initial five years of funding came from the U.S. Department of Defense at \$100 million per year, which was collectively matched by the partnering companies. Since that time, the organization has been successful at reducing 30 percent of costs associated with research and development (R&D) for each new generation of chip miniaturization and has steadily reduced those R&D costs over time.

SEMATECH has expanded its operations from being a U.S.-only research consortium to include companies and researchers from the international market, helping it in its global initiative to be an innovator in the research and development of semiconductors and microchip technology. SEMATECH is also involved with research at the State University of New York’s College of Nanoscale Science and Engineering (CNSE) in Albany, where it relocated its operations in 2011. The NanoTech Complex there became the organization’s permanent headquarters. The CNSE has invested over \$6.5 billion in its facility, which is 800,000 square feet in size. It also has a computer chip production line as well as clean rooms for the chip manufacturing process.

The organization continues to show a strong presence in the industry and participates in various worldwide conferences; it also hosts workshops. SEMATECH delivers papers, presentations, and joint reports at major industry conferences. SEMATECH conducts research on the technical challenges with a focus on higher productivity, miniaturization, and mass commercialization in developing new materials, processes, and equipment for semiconductor manufacturing. With this approach in mind, it has conducted advanced research in new materials, such as those of nanotechnology. The consortium currently performs research in emerging technologies for device structures, metrology, manufacturing, and environment and safety issues involved with those technologies. SEMATECH continues its work at the CNSE while it develops programs in lithography and metrology.

The success of SEMATECH’s partnership with the government is a model of how the private and public sector can collaborate with manufacturing industries to either restore an industry or jump-start a new

sector. The success of this partnership has had an immense effect on the U.S. economy. From the companies that produce the equipment to those that manufacture the chips to unrelated companies that use the chips in their products, most of the success of smaller and more affordable technologies has largely been a result of the success of the chip manufacturing industry. This had a domino effect branching out into other technological fields and paving the way for several innovations, giving rise to innumerable successful technologies and companies associated with them.

Sohel Poojani

See also Vol. 3, Sec. 1: MASER; Single-Chip Microprocessor

Further Reading

Nenni, Daniel. 2014. *Fabless: The Transformation of the Semiconductor Industry*. CreateSpace Independent Publishing Platform.

Turley, Jim. 2002. *The Essential Guide to Semiconductors*. Upper Saddle River, NJ: Prentice Hall.

Solar Energy

Solar energy is a newer, revolutionary form of renewable energy in which light energy from the sun is captured and converted to solar power, which can then be used to power many everyday needs. The earth receives enough sunlight to meet our current and growing energy demands, and solar energy is becoming increasingly popular as we strive to avoid the use of fossil fuels and natural gas. This renewable energy source is an ideal technology to decrease dependence on nonrenewable sources, as it does not pollute nearly as much, and there is a never-ending supply of sunlight.

There are many different technologies involved in solar energy, such as photovoltaic systems, solar water heating, and solar architecture. These structures are designed to get the most energy from the sun as possible. Some combine technologies such as active solar panels and photovoltaic systems. These technologies can be categorized as either active or passive solar; the definition is based upon how the technologies harness and convert heat and light from the sun to solar power.

When sunlight reaches the earth, the intensity of the radiation is actually quite low, and therefore, collectors need a large surface area to capture as much radiation as possible and convert it to either thermal energy or electrical energy. The most common active solar collectors for capturing solar energy are called “flat plate” collectors. These are widely used to heat homes and for hot water. Flat plate collectors generally consist of a black metal plate that is covered by several layers of glass that are heated by the sun’s rays. The heat produced is then transferred to carrier fluids, which are simply air or water, to assist in the solar energy conversion process. The heat that this system provides can be used directly, or it may be stored for later use, such as during cloudy periods or at night when sunlight is not present and energy isn’t being made. These flat plate collectors are efficient in the 20 to 80 percent range, depending on design.

Photovoltaic cells, or solar cells, are another technology used in solar energy, but they convert solar radiation directly into electricity. Albert Einstein, known for his work on the theory of relativity, was the first to define the photoelectric effect in 1906 and 1907, and this paved the way to understanding solar energy. In these cells, light hits the area between two semiconductors and generates a small electric voltage. Although cells don’t produce much power individually, connecting them to create “solar panel arrays” can generate hundreds of thousands of kilowatts of electric power.

Unfortunately, the efficiency of photovoltaic cells is still fairly low, at only about 15 to 20 percent. Their low efficiency, combined with their high cost to produce a moderate amount of power, leads photovoltaic cells to be used mainly in low-power situations, such as for calculators and watches.

Passive solar energy technologies and techniques are a bit different from active solar ones. In passive solar, no external devices are used; this technology takes advantage of its local climate and surroundings to get the most power possible. Passive solar is often involved in the design of structures, as is the case with solar architecture. This practice involves cool roofs or green roofs, and radiant barriers. When constructing buildings incorporating passive solar architecture, engineers and architects take the local environment into account and may align the building to be directly



These Solar Energy Generating Systems (SEGS) in the Mojave Desert use a parabolic trough system to generate solar power. As of 2018, solar power accounts for 30 percent of grid demands, while wind power makes up another 10 percent. (iStockPhoto.com)

in the sun's path to ensure that a large amount of energy can be harnessed. This practice takes into account latitude, altitude, and cloud cover, along with many other factors, to maximize the overall efficiency without breaking the bank.

Solar energy has been around for decades now, but this technology did not take off as it should have until recently. Again, the earth receives enough sunlight in a day to more than power our needs. The main reason it has taken us so long to adopt solar energy technologies is that, although solar energy provided from the sun is “free,” the technology and devices to convert its rays into usable solar power are still fairly expensive. The purchasing and installation of solar panels can cost homeowners tens of thousands of dollars. Although the government often offers tax reductions for homeowners with solar and the power generated has the potential to lower electricity bills, the initial start-up costs for solar energy

are too high for many. Until we can find a way to make these technologies more affordable and readily available for everyone, we will still depend greatly on nonrenewable sources such as petroleum, biofuel, and fossil fuels.

Marissa N. Nahay

See also Nuclear Energy/Nuclear Power Plants; Wind Energy; *Vol. 1, Sec. 3: Solar Compass*; *Vol. 2, Sec. 2: Einstein, Albert*; Hydroelectric Power

Further Reading

- Bainbridge, David A., and Kenneth L Haggard. 2011. *Passive Solar Architecture: Heating, Cooling, Ventilation, Daylighting, and More Using Natural Flows*. White River Junction, VT: Chelsea Green.
- Behling, Sophia, Bruno Schindler, and Stefan Behling. 2000. *Solar Power: The Evolution of Sustainable Architecture*. New York: Prestel.

- Thomas, Randall, and Amory Lovins. 2001. *Photovoltaics and Architecture*. New York: Spon Press.
- Tiwari, G. N. 2002. *Solar Energy: Fundamentals, Design, Modelling and Applications*. Boca Raton, FL: CRC Press.

Space Shuttle

The space shuttle was the first reusable spacecraft in history. Created by the National Aeronautics and Space Administration (NASA) and made possible with a diverse team of thousands of civil servants and industrial contractors, the shuttle program lasted from 1981 to 2011. The five space shuttles—*Columbia*, *Challenger*, *Discovery*, *Atlantis*, and *Endeavor*—had a total of 135 launches. Two critical in-flight failures of the *Challenger* and *Columbia* orbiters caused the deaths of 14 astronauts. Nevertheless, the space shuttle was responsible for the deployment of significant satellites and interplanetary probes. It was a principle ferry in the construction of the International Space Station and enabled the dramatic deployment and in-flight repair of the Hubble Space Telescope. It also helped unite the Russian and American space programs when in 2005, the shuttle *Atlantis* docked with the Russian space station Mir.

The idea of reusable rockets dates back to the 1930s, when Viennese engineer Eugen Sänger (1905–1964) developed plans for a liquid-fueled craft capable of reaching the stratosphere. The idea of reusable rockets did not come to the forefront of imagination in the United States until the early 1950s. German scientist Wernher von Braun (1912–1977) was the most charismatic and effective promoter of this method of travel. In a series of articles for *Collier's* magazine (one of the most highly read periodicals in the United States at the time), he articulated many of the features eventually realized in the space shuttle. Reusable rockets remained in the background until the 1970s, when the space race to the moon between the Soviet Union and the United States came to an end.

After the final Apollo moon mission in 1972, NASA fundamentally reshaped its vision for space. NASA replaced voyages to the moon with a new low-earth-orbit destination accessed by a reusable space

shuttle that launched like a rocket and returned to Earth like a giant glider.

While NASA engineers were initially disappointed that another high-profile mission was not going to replace Apollo, they soon learned to appreciate the challenge of reusability. The idea of reusability was also related to a cultural emphasis on conservation and recycling. In an era of environmental consciousness, Apollo looked expensive and wasteful. For the space shuttle, the majority of the craft (except for the external tank that burned up in the atmosphere), could be used again and again.

Though the Space Shuttle program was a NASA project, Lockheed Martin constructed the external tank, Boeing and Rockwell developed the orbiter, and Thiokol manufactured the reusable solid rocket motor. All of the space shuttles launched from NASA's Kennedy Space Center in Florida. Landings also occurred there, as well as at Edwards Air Force Base in California.

The space shuttle itself was 184 feet in length, while the orbiter was 122 feet. At liftoff, it weighed 4.5 million pounds, and once in orbit, its velocity was 17,321 miles per hour, which meant that the crew witnessed a sunrise or sunset every 45 minutes. Each of its missions cost roughly half a billion dollars and lasted from 10 days to two weeks, during which time the astronauts performed zero-gravity science experiments or other mission-specific tasks. Shuttles had a large bay in which they could transport cargo, like satellites, science equipment, or material for experiments. The bay also held the robotic manipulator arm.

Prior to the first actual mission in 1981, there were three prototype flights with the *Enterprise*. Piggy-backed on a modified Boeing 747 airliner, this Shuttle Carrier Aircraft (SCA) released the *Enterprise* in flight and enabled the astronauts to practice the gliding landing. The SCA also was the vehicle that transported the space shuttle cross-country to Florida when it landed in California.

The first launch, known as STS-1, took place on April 12, 1981, which ironically was exactly the 20th anniversary of Yuri Gagarin (1934–1968), the Soviet cosmonaut, becoming the first human in space. John Young and Robert Crippen were the first astronauts to pilot the *Columbia* on its maiden mission.

The shuttle program came to represent the diversity of American society itself. While the early astronauts were all white males, this changed by the 1980s. In June 1983, Sally Ride became the first American woman in space, and two months later, Guion Bluford became the first African American in space. Hispanics also made their first ventures in this decade with Frank Chang-Diaz's trip in 1986. In 1992, Mae Jemison became the first African American woman in space, and one year later, Ellen Ochoa became the first Hispanic woman there. The other important way that the shuttle mirrored American society was with the inclusion of a senior citizen. NASA did this with a notable name from the past, as John Glenn became the oldest human to fly in space at age 77. The final multicultural achievement was the 2002 shuttle flight of J. B. Herrington, the first tribal-registered Native American to fly in space.

Tragically, the Space Shuttle program will also be remembered for two catastrophic failures. On January 28, 1986, the shuttle *Challenger* lifted off from Cape Canaveral and minutes later exploded over the Atlantic Ocean, killing its crew. This signified the greatest disaster in NASA history and the first time that any American astronaut was ever lost in flight. It became one of the most traumatic moments ever captured on live television. This mission included the first "teacher in space," Christa McAuliffe (1948–1986), and millions of schoolchildren across the nation were watching the launch live on television.

The *Challenger* disaster resulted in a 32-month break in the shuttle program and a months-long investigation. The Rogers Commission determined that the shuttle's O-rings had failed as the result of a design flaw. The commission also found significant communication failures between mission engineers, safety personnel, and high-ranking NASA managers.

Though the space shuttle returned to operational duty, tragedy again marred the program when the *Columbia* disintegrated while reentering the atmosphere over Texas on February 1, 2003, killing all seven members of its crew. The *Columbia*, which was the first shuttle in space, made 27 missions before its 2003 disaster. Many NASA critics argue that the *Columbia* accident was the result of NASA's refusal to institute meaningful institutional change after the *Challenger*

disaster, including the failure to set up a truly independent office for safety.

The final mission, by the space shuttle *Atlantis*, landed at Kennedy Space Center in July 2011. In total, the five shuttle orbiters had logged over a half billion miles in space. There were 335 astronauts that flew on the space shuttle, with 14 dying in the two failed missions.

The shuttle's impact was felt on earth as well as space with several technological spin-offs from the program. These included small artificial heart pumps developed from shuttle fuel pump technology. The shuttle team helped to develop environmentally friendly lubricants. Homeowners now insulate their residences using light, flexible aerogel that NASA developed to insulate shuttle cryogenics. Other shuttle spin-offs include firefighting infrared cameras, prosthesis materials, video stabilization software, land mine removal devices, automotive insulation, and handheld cutters to remove people trapped in wrecked vehicles.

Until another craft is developed, U.S. astronauts rely on the Russian Soyuz spacecraft to reach low-earth-orbit destinations like the International Space Station. The three surviving shuttles are now museum pieces. *Atlantis* is displayed at Kennedy Space Center, the Smithsonian houses the *Discovery*, and *Endeavour* resides at the California Science Center in Los Angeles.

Mark D. Bowles

See also Ride, Sally; *Vol. 3, Sec. 1*: National Aeronautics and Space Administration (NASA); *Vol. 3, Sec. 3*: Hubble Space Telescope; International Space Station; Jemison, Mae

Further Reading

- Cabbage, Michael, and William Harwood. 2004. *Comm Check: The Final Flight of Shuttle Columbia*. New York: Free Press.
- Duggins, Pat. 2009. *Final Countdown: NASA and the End of the Space Shuttle Program*. Gainesville, FL: University Press of Florida.
- Gordon, R. Michael. 2008. *The Space Shuttle Program: How NASA Lost Its Way*. Jefferson, NC: McFarland.

- Hitt, David, and Heather R. Smith. 2014. *Bold They Rise: The Space Shuttle Early Years, 1972–1986*. Lincoln: University of Nebraska Press.
- McDonald, Allan J., and James R. Hansen. 2009. *Truth, Lies, and O-Rings: Inside the Space Shuttle Challenger Disaster*. Gainesville: University Press of Florida.

Strategic Defense Initiative (SDI)

President Ronald Reagan proposed the Strategic Defense Initiative (SDI), a nuclear missile-proof bubble over the United States nicknamed “Star Wars” after the popular science fiction film created by George Lucas in 1977. SDI forerunners Sentinel and Safeguard were terminated, because they were incapable of fulfilling their enormous missions. SDI challenged the long-standing deterrence theory (a reliance on the threat of nuclear retaliation to discourage attack) by threatening to shift the balance of defense capabilities.

Although SDI never worked the way it was intended and was extremely expensive and controversial, it may have helped to bring about the end of the Cold War. Congress cut SDI’s budget dramatically in 1992; however, the threat of terrorism after 2000 enabled President George W. Bush to begin construction of the National Missile Defense (NMD) system, which came to be known as the “Son of Star Wars” program.

During World War II (1939–1945), German scientists attempted to develop intercontinental ballistic missiles (ICBMs), long-range missiles that could hit targets in other continents. In response, the United States commissioned American scientists to conduct missile defense research. In 1945, Edward Teller (1908–2003), later known as the “father of the hydrogen bomb,” wrote a report for the U.S. Navy about the feasibility of defensive capabilities against atomic weapons.

By the 1960s, ICBM technology had been developed, and it was in the hands of the two Cold War (1945–1989) superpowers: the United States and the Soviet Union. In 1966, Teller invited California governor Ronald Reagan to a weapons laboratory in

Livermore, California, for a two-hour briefing on his work with missile defense. Although Teller’s main goal at that time was to secure state support for his research, the meeting left a lasting impression on Reagan.

In 1967, the Soviet Union deployed a missile defense system that used missiles to shoot down other missiles. That same year, President Lyndon B. Johnson ordered the deployment of a U.S. counterpart called Sentinel, which was intended to defend large U.S. cities against incoming missiles. However, if only one nuclear missile got through Sentinel’s defenses, it would spell disaster for any large city. In 1969, President Richard Nixon replaced Sentinel with Safeguard, a plan to defend vital U.S. weapons systems. Like Sentinel, Safeguard was too small to fulfill its huge task. In 1972, Congress cut Safeguard’s funding, and the program was terminated in 1976.

Many American and Soviet leaders came to the conclusion that no technology existed that could provide adequate defense from incoming missiles. Furthermore, if such a system could be developed and deployed by one of the superpowers, it would leave the other nation at a great military disadvantage. Some even argued that an attempt by one of these two nations to develop an effective missile defense system could lead to nuclear war because of pressure placed on the other nation to launch an attack before its defense system was completed.

Since 1949, when the Soviets tested their first atomic bomb, diplomats had relied on the theory of deterrence. The fact that both the United States and the Soviets had atomic bomb technology deterred each nation from using them for fear of retaliation from the other. In 1972, American diplomatic negotiations with the Soviets culminated in the Strategic Arms Limitation Talks (SALT) and the Anti-Ballistic Missile Treaty (ABM), which limited each of the two nations to a maximum of two missile defense sites (each with a maximum of 100 interceptor missiles). In 1974, the two nations signed a follow-up protocol that reduced the missile defense sites to one for each nation.

In 1982, Teller gave a presentation to President Reagan on strategic defense. The next year, Reagan gave a speech (based on Teller’s report) before Congress on the need to fund SDI. The original vision for

SDI was a system of space-based laser-firing satellites. The original plan to put weapons in outer space would have violated the Outer Space Treaty (1967), which had been signed by both the United States and the Soviet Union. Later proposed designs for SDI included land-based weapons that would shoot down missiles with other missiles, subatomic particle beams, or electromagnetic rail guns. All of these proposals would have violated the 1972 ABM Treaty.

Scientists were unable to make the SDI dream a reality. Officials from the U.S. Defense Department estimated that it would take at least 30 years to construct and deploy an effective SDI system. Due to the fact that all of the different versions of SDI required a high level of technological, futuristic know-how that did not exist, journalists created the nickname “Star Wars” for it.

After a decade of research and development, a Congressional report put the total cost of SDI at \$70 billion. Critics charged that SDI was a waste of money. According to some historians, however, Reagan’s commitment to SDI and the Soviet Union’s inability to keep up with U.S. defense spending contributed to the collapse of the Soviet economy. According to this view, by outspending the Soviets, Reagan helped bring about the end of the Cold War in 1989.

After the Cold War, Congress cut SDI funding dramatically. In 2000, President George W. Bush announced that he would replace SDI with NMD, a less expensive missile defense system. NMD created a layered defense system of land-based missiles in Alaska and California that could, theoretically, shoot down incoming missiles at various stages of their flight paths. As a result, the United States withdrew from the ABM Treaty in 2002. Analysts estimated the cumulative 30-year cost of SDI and NMD at \$100 billion.

Rolando Avila

See also *Vol. 2, Sec. 3: Hydrogen Bomb; Vol. 3, Sec. 1: Antiballistic Missiles (ABMs); Space Science and Technology*

Further Reading

FitzGerald, Frances. 2000. *Way Out There in the Blue: Reagan, Star Wars, and the End of the Cold War*. New York: Simon & Schuster.

Reagan, Ronald. 1983. “Address to the Nation on Defense and National Security.” March 23. Ronald Reagan Presidential Library & Museum. <http://www.presidency.ucsb.edu/ws/?pid=41093>, accessed September 25, 2018.

Sustainable Agriculture

Sustainable agriculture is a way of farming that emphasizes a rejection of chemical fertilizers, pesticides, and genetically modified seeds while encouraging a more holistic and natural approach to the land. There are many ways to define sustainable agriculture; its meaning has been changing since the late 1980s. Although it is uncertain who originally created the term, the first person to publish the expression “sustainable agriculture” was Wes Jackson in *New Roots for Agriculture* (1980). As Jackson discusses, the need for sustainable agriculture springs from the fact that globally, crop and livestock production faces many challenges that cause it to be unsustainable. The existing problems with contemporary crop and livestock production and the global challenges that mainstream agriculture faces must be understood before more sustainable agricultural practices can be implemented.

As a result of the industrialization of agriculture, which started in the late 1800s and had its most recent push with the Green Revolution in the 1960s, the small, independent farm economy is currently in collapse. The U.S. agricultural economy is increasingly and extremely dependent on the use of inputs such as fertilizer, groundwater irrigation, and so on, and financial support by the government. The use of fertilizers in this country has led to huge “dead zones” along the Gulf of Mexico where the Mississippi River drains into the ocean. These dead zones are an ecological disaster caused by excessive use of fertilizers, which are mostly unabsorbed by crops and leach into the rivers.

Along with the Green Revolution came a dependency on fossil fuels to run farm equipment that allows for mass production and cultivation of crops. As fossil fuels become scarcer, the economic cost of fossil fuels increases, creating an inefficiency in energy use and costs. The use of fossil fuels is not only economically

nonviable but also contributes to another problem threatening mainstream agriculture: the burning of fossil fuels emits greenhouse gases that are scientifically proven to accelerate climate change. With every passing day, climate change becomes a more pressing global issue. The effects of climate change on global agriculture has been catastrophic in many cases. Climate change has increased the number of droughts and other extreme weather events that have led to or have been a key factor in all of the five famines happening right now around the world. Every one of these issues pushes the need for agricultural practices to become more sustainable economically, environmentally, and socially.

With these challenges in mind, the 1990 congressional Farm Bill defined sustainable agriculture as an integrated system of plant and animal production practices having a site-specific application that would, over the long term, meet certain criteria. Sustainable agriculture must satisfy human food and fiber needs, enhance the environmental quality and natural resource base upon which the agricultural economy depends, make the most efficient use of nonrenewable resources and on-farm resources, sustain the economic viability of farm operations, and enhance the quality of life of farmers and society as a whole.

Sustainable agriculture is meant to support the ecology of the land and efficiently produce food by managing the consumption of resources and minimizing waste. Wendell Berry said that for agriculture to be sustainable, “it must preserve the land, and the fertility and the ecological health of the land,” and “the people who use [the land] must know it well, must be highly motivated to use it well, must know how to use it well, must have time to use it well, and must be able to afford to use it well” (Berry 1990). This perspective on what constitutes productive agriculture agrees with the contemporary definition of sustainable agriculture: that it must be ecologically restorative, supported by society, and economically viable.

The answer to how to make current agricultural practices more sustainable is not simple. What makes some practices more sustainable than others depends on ecological characteristics and the climate of an area, among many other influences. As described in the 1990 Farm Bill, sustainable agricultural practices

are site specific, meaning that for people to create the most sustainable system of agriculture, they must have a comprehensive understanding of the ecology and climate in that area. Some practices that have increased the efficiency of crop production in terms of bushels per acre include advances in farming equipment, manipulation of genes through hybridization or transgenic crops (GMOs), improved farming techniques such as crop rotation, no-till farming, and cover crops. However, the list of different ways that farmers increase the yield, sustainability, or economic viability of their systems seems never to end.

Today, sustainable agriculture is more widespread and culturally meaningful than it has ever been. Women make up a significant number of new, sustainable farmers, and in the process, they are redefining the term “farmer.” The term “organic” is now commonly used in grocery stores. It seems to be possible to find an organic option for almost any grocery product. Organic farming is an agricultural practice that does not contribute to the problem of the “dead zones” and other ecological issues stemming from the use of synthetic fertilizers, herbicides, and pesticides. Organic farming has proved to be productive as long as it is managed well.

Instead of using synthetic fertilizers or animal derived fertilizers, farmers can grow “green manure crops,” which are basically cover crops such as lentils that can fix nitrogen back into the soil. Once these crops are grown, instead of harvesting them, farmers cut the crops off and till them into the soil to replenish its organic matter. Cover crops are crops that are planted to decrease soil erosion, weeds, and pests while also increasing soil quality and soil fertility. Cover crops work best in areas with higher levels of annual rainfall, such as in the eastern part of the United States, because they should improve the soil of the land and keep it free of weeds without using all of the water needed by the cash crop. Cover crops are an alternative to leaving a field fallow. In places of lower precipitation, such as in the western part of the United States like Montana and eastern Washington, it is common practice to leave a field fallow during the summer months so that precipitation soaks into the soil to be used by winter wheat or spring wheat once it is planted.

Modern farmers, particularly those wishing to resist the incursions of corporate agriculture, are increasingly turning to sustainable farming, particularly in light of the fact that multitudes of studies prove that agribusiness-driven monocultures are bad for the environment, bad for human health, and bad at feeding the world.

Emma E. L. Burke

See also *Vol. 1, Sec. 2*: Three-Piece Iron Plow; *Vol. 1, Sec. 3*: Combine Harvester; Deere, John and Deere and Company; Polished Steel Plow

Further Reading

- Berry, Wendell. 1990. *What Are People For?* New York: North Point Press, 206–207.
- Falk, Constance. 2010. *Cultivating an Ecological Conscience: Essays from a Farmer Philosopher*. Lexington, Kentucky: University of Kentucky Press, 267.
- Jackson, Wes. 2011. *Nature as Measure: Selected Essays of Wes Jackson*. Berkeley, CA: Counterpoint.
- Sachs, Carolyn, et al. 2016. *The Rise of Women Farmers and Sustainable Agriculture*. Iowa City: University of Iowa Press.
- Thistlewaite, Rebecca. 2013. *Farms with a Future: Creating and Growing a Sustainable Farm Business*. New York: Chelsea Green.

Wind Energy

Wind energy is a renewable energy source obtained by rotating blades of windmills or turbines via wind power. Wind energy has been used in daily work such as pumping water and grinding grain for over 4,000 years. However, in the 20th century, wind energy has been successfully and economically converted to general electricity production and the resultant power converted to the grid system.

The world's first wind farm was built in New Hampshire, with a capacity of 600 kilowatts (KW), in 1980. Since then, the United States and a few other European countries such as Germany, Denmark, and Holland have contributed significantly in improving

the design and efficiency of the wind energy generation system. In 2008, the United States surpassed long-time leader Germany by producing 20 gigawatts (GW) of wind energy. However, in 2013, most wind energy was produced by China (91.4 GW), followed by the United States (61.1 GW) and Germany (34.2 GW).

The wind energy generation system is divided into two major categories based on the size of the turbine and type of customer. They are as follows: “utility-scale” wind systems with large turbines (larger than 100 KW capacity), primarily used by the electric utility companies and power system operators; and “distributed,” or “small wind,” systems with turbines (100 KW or less capacity) that are used to provide electricity to residential homes, farms, or small businesses. There are also “off-shore” wind farms in coastal areas, which have experienced significant growth particularly in Europe due to the presence of stronger winds, better technologies, and less impact on real estate values. The top three countries with the largest off-shore wind capacities are the United Kingdom, Denmark, and Germany.

Wind turbines are complex systems and in need of technical expertise from many fields such as mechanical, electrical, electronics, construction engineering, and meteorology. Most wind turbines consist of a steel tubular tower, which supports both a “hub” securing wind turbine blades, and the “nacelle,” which houses the turbine's shaft, gearbox, generator, and controls. Wind rotates the turbine blades, and the rotating blades make an internal shaft spin; the shaft is connected to a gearbox, which increases the speed of rotation significantly. A generator connected to the gearbox then produces electricity; thus, wind energy is converted to mechanical energy and, in the end, to electrical energy. Wind assessment equipment in the control system helps the turbine to rotate into the face of the wind and to optimize energy captured by adjusting the angle, or “pitch,” of its blade.

The World Wind Energy Association (WWEA) is the driving force behind the promotion and deployment of this form of energy worldwide as a clean alternative to fossil fuel and nuclear energy. There are currently three different concepts available for generating electricity from the wind turbine: (1) the Danish concept, (2) the pitch concept with a synchronous generator, and (3) the pitch concept with a doubly

fed, asynchronous generator. Technical expertise as well as the implementation strategies, either for grid-connected or stand-alone wind turbines, are provided by the WWEA to its members. The WWEA expects that the demand for wind energy will grow at a faster pace in the near future, and it predicts that wind capacity will reach more than 700 GW by 2020.

In the United States, the American Wind Energy Association (AWEA), a not-for-profit organization, provides information to the general public and businesses about wind energy and endorses policy on Capitol Hill and across the states to enhance the future growth of wind energy. Its Web site is a valuable resource for finding all activities and information regarding wind energy. The Community Wind Working Group (CWWG) was formed by the AWEA in 2009 to pursue the growth and interest of “community wind” projects. These projects are controlled and financed by local landowners or individuals in agricultural or rural communities. Small or midsize wind turbines are used for these projects. The AWEA is also exploring the huge potential for launching the off-shore wind system. According to its data, off-shore systems are capable of generating up to four times the current capacity of the U.S. electrical system. The U.S. Department of Energy stated in its report that off-shore wind will contribute significantly to meeting the goal of “20% Wind Energy by 2030.” AWEA closely works with the U.S. Environmental Protection Agency to reduce emissions of greenhouse gases and is committed to meeting the growing need for energy in the United States. Research suggests that wind energy has several benefits, including a significant reduction of carbon dioxide, sulfur dioxide, and nitrous oxide emissions and the conservation of billions of gallons of water.

The drawbacks of wind energy are the high initial investment cost, the high noise level produced by the turbine blades, and the visual impact of the wind farms on the public. Also, the ecological impact of wind turbines on wildlife, particularly on bats, has been a major concern for environmentalists. AWEA and the wind industry have taken initiatives to reduce the harmful effect of turbines on bats and other wildlife. AWEA, Bat Conservation International, the U.S. Fish and Wildlife Service, and the National Renewable Energy Laboratory have formed the Bats and Wind



The wind farm at Altamont Pass is one of the nation's first of its type, and it remains the largest concentration of wind turbines in the world. (Terrance Emerson/Dreamstime.com)

Energy Cooperative (BWEC) to research the influence of wind turbines on bats and to investigate new techniques in reducing their harmful effects, such as acoustic deterrents and potential operational changes to wind turbines.

Mousumi Roy

See also Nuclear Energy/Nuclear Power Plants; Solar Energy

Further Reading

Kunz, Thomas H., Edward B. Arnett, Wallace P. Erickson, Alexander R. Hoar, Gregory D. Johnson, Ronald P. Larkin, M. Dale Strickland, Robert W. Thresher, and Merlin D. Tuttle. 2007. “Ecological

Impacts of Wind Energy Development on Bats: Questions, Research Needs, and Hypotheses.” *Frontiers in Ecology and the Environment* 5, no. 6: 315–24.

Pasqualetti, Martin J., Paul Gipe, and Robert W. Righter, eds. 2002. *Wind Power in View: Energy Landscapes in a Crowded World*. Waltham, MA: Academic Press.

World Wide Web. See Internet

Wozniak, Steve (1950–)

Beside Bill Gates of Microsoft, Steve Wozniak is known as one of the electronic entrepreneurs who invented the information age by inventing the Apple personal computer and cofounding Apple Inc. Due to media coverage and his position as the top sales representative of the company, cofounder Steve Jobs gained more notoriety, but it was the technical talents of Wozniak that ensured that the company had a product worth selling. In later life, he left the company to new management and focused his attention on philanthropy.

He was born on August 11, 1950, in San Jose, California, to Margaret Elaine, who worked in the home, and Jerry Wozniak, who worked in the electrical engineering field and thus offered his son an early love of technology. His father’s position at Lockheed Missiles and Space Company meant the family kept abreast of the newest ideas emerging in the field. The Wozniaks valued education and its role in promising their children successful careers. Encouraged by both parents, Wozniak built ham radios and game devices while still in elementary school. He won awards for science and tech projects throughout his education and in high school helped his electronics teacher program computers at the local electronics company, Sylvania.

College proved more of a challenge as the young man moved from the University of Colorado, Boulder, to DeAnza Community College, to the University of California, Berkeley, which he attended in 1971. That summer, Wozniak worked on mainframe computers for Hewlett-Packard and eventually met fellow employee Steve Jobs. While they worked at Hewlett-

Packard by day, the two new friends attended meetings of the Silicon Valley Homebrew Computer Club at night. The Club became a hub of up-and-coming computer professionals and allowed Wozniak a sounding board for new ideas.

In 1973, Jobs began working at Atari Inc. and brought an offer to Wozniak to help create more efficient circuit boards for the company’s arcade games, an after-hours project that could earn them extra cash. Wozniak succeeded and they earned the bonus, though in later years, Wozniak discovered that Jobs had lied about how much it was and kept the lion’s share for himself, an act that harmed their friendship and business partnership.

Wanting to impress their friends in the Homebrew Club, Wozniak began working on what would become the Apple I personal computer in 1976. The desire to create something fun that focused on being user-friendly became a motto that continued to fuel the company he founded through its work on cell phones and beyond. Back then, all the electronic work—designing the hardware, the circuit boards, and the operating system—was done by Wozniak. Jobs handled the marketing and was the driving force behind the idea of forming a company to sell this new, user-friendly home computer. He formed a relationship with the Byte Shop, a computer sales office run by Paul Terrell in Mountain View, California. When the first 50 boards sold quickly, Terrell wanted more, and Wozniak and Jobs knew they had a valuable product on their hands.

At this point, Wozniak knew he could risk resigning from his job at Hewlett-Packard to focus on research and development of new products, which began with the Apple II, the first personal computer that could display color graphics and included the BASIC programming language. Soon he developed a way to connect the Apple computer to a printer, and then he developed the floppy disk for memory storage, acts that made their computers more and more popular with average, nonhobbyist consumers. By the end of 1978, Apple sales had increased 10 times, making Apple one of the fastest-growing companies in the United States. Thanks to Jobs’s efforts, more than 300 dealers carried Apple computers, and by 1979, Apple had more than a thousand employees.

This continued success convinced the partners that it was time to take the company public, an act that made them both millionaires in 1980. Wozniak started designing a new computer called the Lisa, named for his daughter, but it failed to catch hold of the now-cluttered personal computer market. He quickly reconfigured a cheaper version called a Macintosh, which came with a mouse, file folders, and pull-down menus and could display photos. This one sold. A flying accident took Wozniak away from his work for a time, but by 1983, he returned to the product development department to be the head engineer and motivational influence for the Apple workforce. By early 1985, Wozniak again left Apple and sold most of his stock.

As a philanthropist, Wozniak continued to focus on technology and bringing it to those less financially capable of purchasing high-end products. In 1990, he helped found the Electronic Frontier Foundation and was the founding sponsor of the Tech Museum, the Silicon Valley Ballet, and the Children’s Discovery Museum of San Jose. He also donates money and personal time to his local school district to make sure that students can work with the latest technology.

In his career, Wozniak has been honored with several major awards, including the 1979 ACM Grace Murray Hopper Award and the 1985 National Medal

of Technology (shared with Steve Jobs) from President Ronald Reagan. In September 2000, Wozniak was inducted into the National Inventors Hall of Fame, and in 2001, he was awarded the seventh annual Heinz Award for Technology, the Economy and Employment. Outside the United States, Wozniak was awarded the Global Award of the President of the Republic of Armenia for Outstanding Contribution to Humanity through IT in 2011. His other awards are too numerous to mention.

Rosanne Welch

See also Apple; Gates, Bill; Jobs, Steve; Microsoft; *Vol. 3, Sec. 1*: Atari; Hopper, Grace

Further Reading

- Isaacson, Walter. 2015. *The Innovators: How a Group of Hackers, Geniuses, and Geeks Created the Digital Revolution*. New York: Simon & Schuster.
- Knuth, Donald E. 2011. *Leaders in Computing: Changing the Digital World*. London: BCS, The Chartered Institute for IT.
- Wozniak, Steve. 2007. *iWoz: Computer Geek to Cult Icon: How I Invented the Personal Computer, Co-Founded Apple, and Had Fun Doing It*. New York: W. W. Norton.

3. The New Millennium (2000–Present)

OVERVIEW

Technology and technological advances this millennium have surpassed even the expectations and dreams of the most avid science fiction fan. From the advent and evolution of the smartphone to the printing and cloning of human organs, technology's mandate to address the challenges of human existence has been met and continues to expand. New technological waves throughout this period have encompassed the arenas of communication, medicine, education, food-stuffs, and energy, to name a few. The federal government and major corporations like Apple, Amazon, Microsoft, Google, Intel, and Dell have continued to pioneer technology that changes people's interactions with each other and the world at large. In this current era in American technology, the sky is the limit.

Technological advancements in the areas of transportation and energy, such as electric cars and biofuels, are signifiers of the basic mandate of technology as a "practical" application of knowledge, as these technologies seek to advocate and support long-term protection of nature and natural resources. Here in the United States, the first successful electric car made its debut around 1890 thanks to William Morrison. His six-passenger vehicle capable of a top speed of 14 miles per hour was little more than an electrified wagon, but it helped spark interest in electric vehicles. Renewed interest in the electric car came with the introduction of the Toyota Prius in Japan. Before the Prius could be introduced in the United States, Honda released the Insight hybrid in 1999, making it the first hybrid sold in the States since the early 1900s. The other event that helped reshape the electric vehicles market was the announcement in 2006 of the Silicon

Valley-based Tesla Motors luxury electric sports car that could go more than 200 miles on a single charge. In 2010, Tesla established a manufacturing facility in California. In the short time since then, Tesla has won wide acclaim for its cars and has become the largest auto industry employer in California. Tesla's announcement and subsequent success spurred many big automakers to accelerate work on their own electric vehicles.

In late 2010, the Chevy Volt and the Nissan LEAF were released in the U.S. market. The Energy Department helped build a nationwide charging infrastructure, installing more than 18,000 residential, commercial, and public chargers across the country. Automakers and other private businesses also installed their own chargers at key locations in the United States, bringing today's total of public electric vehicle chargers to more than 8,000 different locations with more than 20,000 charging outlets. At the same time, new battery technology helped to improve a plug-in electric vehicle's range. In addition to the battery technology in nearly all of the first-generation hybrids, research also helped develop the lithium-ion battery technology used in the Volt. More recently, research and development helped cut electric vehicle battery costs by 50 percent by 2017 while simultaneously improving the vehicle batteries' performance. This has helped to make electric vehicles more affordable for the average consumer. Inquiries into alternative fuel sources by the federal government and corporations in America have evolved and improved to support the sustaining of energy resources. Alternative energy sources like Ivanpah, the largest concentrating solar power (CSP) plant in the world, located in the Mojave Desert of California, with a field of heliostat

mirrors have the capacity to generate enough clean electricity to power over 94,000 average American homes. The use of alternative processes for energy and material building has been a significant event during this period.

Seeing the World in 3-D

Alternative, 3-D technology has been part of the American scene since roughly 1915. However, since the beginning of the current (21st) century, advances and innovations in 3-D printing, 3-D television, and 3-D filmmaking have charted new pathways for entertainment, engineering, and medical advancements. The construction of a physical object from a three-dimensional digital model by creating and laying many thin layers of material atop one another is the process of 3-D printing. This manufacturing process has provided benefits to humankind in a variety of industries, such as building materials, space technology, automotive construction, civil engineering, fashion, and the creation of foods. It even has the potential to be used for biological organ creation.

In 2000, a Clemson University bioengineer modified inkjet printers to dispense biological ink and made 3-D objects. In 2007, one of the first bioprinting companies, Organovo, was founded. It has been successful to date with printing out liver tissue samples that are used for drug testing and research. The 3-D printer may be one of two common types. It may be a fused deposition modeling (FDM) printer, which is similar to a 2-D inkjet printer but having an extra axis enabling each layer to be formed when a thin stream of melted material is deposited through a spout. The other prominent model is the selective laser sintering (SLS) printer, which uses a scanning laser beam to build up an object from powdered material. Starting with a computer-aided design (CAD) file, the software slices the design into hundreds or thousands of horizontal layers. Once the 3-D printer has read the file, it creates each layer exactly. The layers are meshed together, creating a three-dimensional object. Another name for 3-D printing is “additive manufacturing,” as each part of the object is created in successive layers in what is an additive process. Today, basic 3-D printers are small enough to sit on a desktop, cost only a

few hundred dollars, and are available for anyone to buy. Additionally, 3-D printing can be done through Internet printing companies. Customers upload their 3-D printing files through an Internet-based service, choose the proper production selections, and submit. The object is printed at another location and then delivered to the customer. Alongside 3-D usage in the area of printing, technological developments in 3-D television have also found their way into the home of the average consumer.

3-D television provides depth perception for the viewer through the use of techniques such as stereoscopic display, multiview display, and 2D-plus-depth. Most modern 3-D television sets use an active shutter 3-D system or a polarized 3-D system, and some are autostereoscopic, allowing the viewer to watch shows in 3-D without special glasses. In early 2010, due to the popularity of 3-D in theaters, several companies, including LG, Phillips, and Sony, developed technology to create 3-D televisions as well as IMAX and Sony delving into creating 3-D television networks, like the short-lived 3Net carried on DirecTV from 2011 through 2014. By 2014, most 3-D television networks had come and gone due to a lack of demand for the service in homes.

Contemporary 3-D technology in filmmaking was primarily a feature in IMAX theaters and has been around since 1986, when the film *Transitions* became the first 3-D movie to be paired with polarized lenses rather than the typical anaglyph glasses. Polarized lenses permit an image to be emitted toward the viewer and then refracted through the glasses. Because each lens is polarized differently, the image received by each eye is different. Consequently, when the brain receives these two similar but different images, it combines them into one—a 3-D image. A 2004 documentary on the *Titanic* illustrated advances in HD video cameras and digital film, which soon found their way into the commercial film market with the release of the digitally remastered (DMR) IMAX 3-D movie *The Polar Express*. The success of this 3-D venture helped propel the competition as newer, more improved technologies began to emerge. These included the 2006 releases of *Monster House* and *The Nightmare Before Christmas* on XPAND 3D, RealD, and Dolby 3D. RealD 3-D cinema technology is a polarized 3-D

system that uses circularly polarized light to produce stereoscopic image projection. The MasterImage 3D MI-CLARITY3D system for cinemas is a differentiated 3-D system that is based on the projector presenting a spinning polarized filter, which contains alternating segments of circularly polarized material. Mounted in front of the projector lens, this filter is synchronized to the projected images, giving each frame a polarization perpendicular to the previous one, which can be viewed with polarized 3-D glasses. By 2007, the anaglyph glasses were replaced for the most part with polarized lenses or LCD shutter glasses. No other film exemplified the advancements in 3-D filmmaking then the highest-grossing film to date, James Cameron's *Avatar*, which was filmed with custom-built cameras and 3-D software.

The Impact of Laser Technology on Life

Important achievements in the technology of this time included ongoing developments in laser technology. Since the FDA approved lasers for the removal of facial wrinkles in 1996, the use of lasers for cosmetic treatments has boomed. Throughout the first decade and a half of the 21st century, the use of laser technology has expanded exponentially. Lasers are also used for treating industrial surfaces. They can toughen and blend surface materials in targeted areas with great precision. Laser-cutting of manufacturing parts reduces production costs. Color laser printers that could access the Internet were on the market by 2000, and by mid-2005, models from Samsung and Konica were affordable to the layman. Laser pointers have been used to distract basketball players on the free-throw line, made law enforcement officers worry that they're a target for snipers when they see laser light on their chests, and disrupted air travel. A major milestone in the laser industry came in 2006 with the introduction of the high-capacity optical-storage technology Blu-ray disc.

Laser application expanded throughout the first decade of the 2000s. One major factor in the United States was the growth in importance and enforcement of homeland security following the terrorist attacks of September 11, 2001. In 2003, the U.S. military began developing a system of green and red lasers for use in

the airspace around Washington, D.C. In operation by 2005, these beacons are visible up to 25 miles away and are used to warn pilots who enter the 2,000-square-mile air defense identification zone surrounding the nation's capital. In January 2010, high-power quantum cascade lasers (QCLs), with their widespread potential for applications in all areas of security, became part of the technological landscape. With an additional 150 different kinds of lasers for a variety of commercial and scientific uses such as tattoo and hair removal, the treatment of skin abnormalities, and general surgery, by the end of 2009, this technology was well established in many industrial laser processes. As of 2009, light-emitting diodes (LEDs) were penetrating the lighting market, while in Chicago, physicians at Rush-Presbyterian-St. Luke's Medical Center pioneered a new, if somewhat controversial, laser-based treatment for angina, the pain that accompanies heart disease.

Technology in the Medical World

Additional developments in medical technology occurred in AIDS and stem cell research, cloning techniques, and robotic surgery, among other areas. In 2002, the first rapid HIV diagnostic test for use in the United States that provides results with 99.6 percent accuracy in as little as 20 minutes was approved by the Food and Drug Administration, and in 2012, it also approved the first at-home HIV test. Although controversial since its inception, stem cell research advanced to the point that in February 2012, researchers at Cedars-Sinai Medical Center and Johns Hopkins University published results from a clinical trial in which adult stem cells were extracted from patients following a heart attack, new cells were grown in a petri dish, and these were then returned to the patient's heart. In the first demonstrated case of therapeutic regeneration, the treatment decreases scarring and leads to regrowth of heart tissue. In the cloning arena, John Sperling and his wife, Joan Hawthorne, opened Genetic Savings & Clone for the purpose of cloning pets for individuals who could afford to pay for the service. In 2001, the process was used to successfully clone a cat named Copy Cat, or CC, who had a litter of her own healthy kittens in 2006—the first time that a

cloned pet gave birth. In 2015 at Harvard University, processes were being invented and tested to save endangered species as well as leading to the possible cloning of extinct animals like the woolly mammoth.

Prosthetic and implant technology also significantly evolved during this time. Approximately 2 million amputees in the United States wear prosthetic limbs. Since the first-known wooden toe, prosthetic design has advanced to include high-performance running blades, sensors, and microprocessor-controlled responsive legs and feet for navigating varying terrain as well as motorized hand prosthetics. Developments in technologies such as robotics, brain-computer interfaces, and 3-D printing have helped advance the field of prosthetics. Robotic surgery, which uses a computer as a conduit between the surgeon and the surgical tools used on the patient, has been found to make surgery safer and more efficient. Robotics also offers motion scaling, which means that a surgeon's wide hand movements can be reduced to fine movements at about a one-tenth scale, allowing for accuracy in tight spaces. In 2000, the da Vinci Surgical System broke new ground by becoming the first robotic surgery system approved by the FDA for general laparoscopic surgery. Robotics-assisted surgery has become enormously popular around the world, with over 1.5 million procedures from hysterectomies to heart valve repairs performed in 2011 alone. By 2013, an FDA survey noted that surgeons who used da Vinci were able to have some patients with cancer avoid chemotherapy.

Technology in Education

From the operating room to the classroom, technological innovations are advancing the human condition. Since the founding of the Academy by Plato in 389 BC, education has been the heart of a civilized society, and technology has always been at the forefront of human education. In looking at where educational methods and tools have come from and where they are going in the future, technology's importance in the classroom is more evident now than ever. Educational technology is anything that enhances classroom learning in the utilization of blended or online learning. In the field of educational technology, one of the major sources of information utilized in this millennium is the Wikipedia online encyclopedia founded in 2001 by Larry

Sanger and Jimmy Wales. Wikipedia is an open-source, free online encyclopedia that aims to allow anyone to edit articles and is ranked among the 10 most popular Web sites globally. Originally only in English, Wikipedia has expanded and has articles in over 250 different languages, although the English-language version with over 5 million individual articles is still its most visited site. There are also learning management systems (LMSs) such as Blackboard, Canvas, and Moodle that are utilized in K-12 education, corporate training, and at colleges and universities. Learning management systems are software that can be used to deliver, track, and manage training and education. LMSs range from systems for managing training and educational records to software for distributing courses over the Internet and offering features for online collaboration. Moodle is a free-to-download open-source course management system that also has platforms for distance learning courses, as does Eliademy, another free, but cloud-based, course management system. Students growing up in this digital age have extensive exposure to a variety of media. Major high-tech companies such as Google, Verizon, and Microsoft have funded schools to allow them to teach students through technology. Canvas is another LMS that provides a modern user interface. Canvas operates as a software service using Amazon Web Services in the cloud. Additionally, classroom tools such as the iClicker, introduced in 2005, allow teachers to poll students and get results in real time. According to research by 2009, 97 percent of classrooms had one or more computers, and 93 percent of classroom computers had Internet access. For every five students, there was one computer. Instructors stated that 40 percent of students used computers often in their educational methods, in addition to interactive whiteboards and digital cameras. Of college students more recently, 89 percent owned a laptop, and over 85 percent had a smartphone (Pearson.com 2015).

Additional tools in technology and learning have coalesced with the emergence of the e-book and the e-reader. With the creation in the 1970s of the first e-book library known as Project Gutenberg, there was a need for a way to access these materials. An electronic book (or e-book) is a book publication made available in digital form, consisting of text, images, or both, readable on computer monitors or other

electronic devices. Not all e-books have a hard-copy equivalent. Almost any computer device that features a controllable viewing screen can also be used to read e-books, including desktop computers, laptops, tablets, and smartphones. However, it was not until Amazon unveiled the Kindle electronic book reader in 2007 that the e-book became a mainstay in the average American life. Produced under the direction of its founder and CEO, Jeff Bezos, Amazon's Kindle hit the market with 250 MB of internal storage and a six-inch display/touch screen. The original Kindle was only sold in the United States, and all available stock sold out within six hours. This limited showcase illustrated the demand for a product that allowed any reader to hold hundreds of books in their hands at once. New technology, added roughly every year since 2009, included larger display sizes, adjustable fonts, larger storage, a text-to-speech feature that allowed the Kindle to read books aloud to the reader, and the Paperwhite edition of the Kindle, whose LED lights allowed people to read in the dark. Due to the demand for this technology, Kindle software has been developed for use on numerous devices and platforms, including Microsoft Windows, iOS, BlackBerry, Mac OS X, Android, webOS, and Windows Phone. In April 2011, Kindle customers became able to borrow books from almost 12,000 of the nation's libraries that purchased digital or e-books. In an attempt to garner a part of the e-reader market, Barnes and Noble, in November 2009, released the Nook e-reader, which included a color touch screen and Wi-Fi accessibility. While still in production, the Nook and other e-reader technologies have never met the demand or customer appreciation of the Kindle. Subsequently, in April 2016, Amazon unveiled the Kindle Oasis. With one of the lightest weights in e-book history at 131 grams, a redesigned grip, buttons for page turning, and a charging cover that can give the reader up to months of battery life, the Kindle Oasis keeps Amazon at the fore of e-reader technology. A major component of the e-reader market is its touch screens. There are several uniquely different types of touch screen technologies with different methods of sensing touch.

Touch screen technology took a huge step into the limelight with the 2007 release of the Apple iPhone. The iPhone introduced an accurate, inexpensive,

multitouch screen. The multitouch screens used by the iPhone rely on a carefully etched matrix of capacitance-sensing wires. The iPhone revolutionized the cell phone industry, and the technology it displayed has changed the way people communicate. This new device introduced the world of mobile apps allowing and encouraging people to communicate with each other through programs like Skype, text messaging, and e-mail through mobile devices. Additionally, people view videos through YouTube and share photos instantaneously through Web sites like Instagram, Twitter, and Tumblr. Throughout its many incarnations, the iPhone has only risen in popularity, with an estimated 90 million Americans owning iPhones as of 2016. The iPhone also made it easy to play music without an additional MP3 player.

Advances in the production, distribution, and consumption of music have evolved to the point that one can consume an entire concert from the privacy of one's home. Apple in the 21st century began its current reign in advanced technology with the unveiling of the iPod MP3 music player, one of the most notable and revolutionary technologies to advance music enjoyment. Released by Apple Inc. in October 2001, the iPod was a portable electronic device for playing and storing digital audio and video files. Measuring four inches in height and weighing 6.5 ounces, at the time of its release with 5 GB of storage, it was touted as putting "1,000 songs in your pocket." The early iPod had a scroll wheel with four buttons and was only compatible with Mac products; users had to add music to their iPods from CDs or other online sources. Subsequent incarnations of the iPod could store photos; there was the iPod mini and also the Nano, which went on to become the largest-selling music player in history to date; there followed the iPod shuffle, the first MP3 player with flash memory—an electronic medium that can be electrically erased and reprogrammed. The iPod touch was hailed as an iPhone without a phone or camera. Released in September 2007, it used the same operating system as the iPhone and offered double the storage capacity.

Technology Turns the Music World Upside Down

Meanwhile, at the production level, recording and mixing of sound have seen massive advances. There

are a tremendous number of devices available to the modern musician, from DAWs to synthesizers, to social media and music-streaming services. The availability of these technologies finally took music out of the hands of record labels and placed it in the hands of music makers. Music-editing software, or digital audio workstations (DAWs) exist today that are priced under \$100, are easy to learn, and accessible to the novice mixer. There are many free and open-source software programs that can enable a DAW. Digital audio programs such as *JACK* allows any JACK-aware audio software to connect to any other audio software running on a computer system. This allows mixers to use multiple programs for editing and synthesizing, as well as ensuring sound quality. Another program, *Audacity*, is a free, open-source digital audio editor that can run on Microsoft Windows but also on OSX and Linux. It is particularly popular in the podcast community. Other open-source music production programs include virtual synthesizers and MIDI controllers. Technology in the form of software and file sharing has also heavily affected and influenced the consumption of entertainment like music and films.

The leader in portable music and media distribution, Apple iTunes, was introduced in January 2001 and originally was only available for use on the Mac operating system. The original iTunes digital jukebox software started off as a way to access and play music. In 2003, the iTunes Music Store, with 200,000 songs at 99 cents each, was introduced. An expanded user base followed as iTunes version 4.1 added support for Microsoft Windows platforms. By 2006, iTunes sold its billionth song while also selling feature-length movies and television show episodes. Since its inception, it has developed into a sophisticated multimedia content mainstay. Currently, the iTunes store allows its users to purchase music, films, television shows, audiobooks, and applications; they can also manage media, create playlists, and synchronize content across multiple devices and operating systems.

Broadening the Technological Playing Field through Open-Source Software

Other forms of entertainment distribution have also found their way onto the scene through open-source

file-sharing technology. File sharing is the free distribution and providing of access to digital media such as computer programs, audio and video files, and even e-books. Major software platforms that employed this technology were LimeWire and BitTorrent. Open-source technology is software that is freely distributed and allows distribution in source code as well as compiled form. There must be an easily found means of obtaining the source code for no more than a reasonable reproduction cost, preferably downloading via the Internet without charge. The purpose is to make evolution of the software easy; therefore, access to modification must be easy. In 2000, the StarOffice office suite was released as free software, and in the summer of 2003, the Wikimedia Foundation was announced and became integral to the development of Wikipedia, an online collaborative encyclopedia written for and by the people who use it. Mozilla Firefox, a popular Web browser, was released in 2004. In 2008, Chromium, which forms the majority of the code in Google Chrome, was released. During this time, Google created and released Android, initially giving it away for free. Android has since become the most popular mobile platform in the world. Chromium OS, released by Google in 2009, has since been employed in a variety of devices, including Chromebooks. Currently, the number of open-source software packages in use is so large that it is virtually impossible to make a comprehensive list. Adding to the success and continued expansion of file sharing are the search engines, which have also evolved and become mainstays of the technological revolution.

Search Engines Became the Card Catalogs of the Future

Search engines use “spiders,” which search the Web for information. They are software programs that request pages much like regular browsers do. In addition to reading the contents of pages for indexing, spiders also record links. There are also search engines that use a search model in which they do not gather, warehouse, or sell data that identifies the user. All major search engines have a limited review process; relevant information is driven by automated search algorithms. Innovative technology in search engines has included providing almost immediate search results, product ratings, conversions

of units and currency, the ability to perform simple mathematical calculations, definitions of terminology, and even document language translation. Pay-per-click ads allow search engines to sell targeted traffic to advertisers on a cost-per-click basis. Typically, pay-per-click ads are keyword directed, but some engines may use local targeting, behavioral targeting, or allow merchants to bid on traffic currents based on demographics. Private search is also finding a market, but it still represents a tiny fraction of overall search engine usage.

Google has become and remained the leader in search engine technology. Since 2003, Google has come out with many advanced filters and crawling patterns to help make links easier to access. Google has also exponentially expanded its search engine domain with the 2004 launches of Gmail and Google Scholar, an academic search program, and the early 2005 introduction of Google Maps. The contemporary search engine market is controlled by a few large companies whose combined search volume makes up over 97 percent of the total global market. Google is in the lead, followed by Bing and Yahoo. In 2011, Google, Yahoo, and Microsoft created Schema.org to support a fuller range of tags that Web sites use to convey better information, illustrating the constant updating and upgrading of the search process. Google is used more in mobile searches because of a deal with Android phone manufacturers to set Google as the default search provider as well as signing a deal with Apple to be the default Web search service in Safari on iPhones, iPads, and Mac computers. Advances such as these in software and Internet use are supported by improvements in the hardware that is used to access it.

Taking Your Tech with You Everywhere

Portable devices with the ability to provide wireless connectivity to games, news, and entertainment, like laptops, iPads, and tablets, have transformed the human condition through changing the way information is processed and communication is proffered. Although the personal computer has been in production in one form or another since the 1980s, a pivotal moment in personal computing history came in 2002 when Microsoft updated the operating system of its tabletop personal computer to Windows XP. Personal mobile

computers took off, aided by the introduction and widespread availability of Wi-Fi in the home and designated “hotspots” throughout the landscape. Companies like Dell, Hewlett-Packard, and Sony all worked to get into the laptop market, juggling to provide the lightest and most user-friendly models. However, most notable was the April 2010 introduction of the Apple iPad, which revolutionized personal computing. The iPad can shoot video, take photos, play music, browse the Web, and receive and send e-mail. From its original inception, the iPad has evolved to include a mini iPad and retina display. Since the takeover of the tablet market by Apple, other companies, most notably Samsung with an Android operating system, have provided alternative platforms for tablet use. New technology on the market includes the phablet, a phone-and-tablet hybrid.

The mobility of personal computing and access to the Internet has led to the largest engagement with digital mediums in humankind’s history. The 21st century has seen the exponential growth of social media and social networking sites. Social networks seem to fulfill our need to connect with one another. The social life that people once found in face-to-face communities is now found in online communities. There are many prominent social networking sites used by both the individual and the corporate world. Sites like LinkedIn (2002), a business connection site; Myspace (2003); and Twitter (2006) have illustrated the power of technology to shape and mediate the human experience. One of the giants in this spectrum is the video-sharing site YouTube. With the motto “Broadcast Yourself,” this site is arguably one of the foremost sources of social networking and social media. The leader in this area as of 2018 is Facebook, yet it also serves as an example of how swiftly customer tastes change, as it completely displaced Myspace when it arrived in 2004. Founded in a dorm room by Mark Zuckerberg, Facebook has grown from a college networking site to the largest networking connector on the planet. Facebook is available in over 70 different languages and is found on every continent on the planet. Facebook technology is entrenched in all aspects of American and global culture.

Technology and continued technological advancement in the United States is not just for the scientific community. It has become so embedded as part of the

infrastructure of American society that a fair was created to celebrate it. Founded in the San Francisco area in 2006, Maker Faire is a gathering of inventors, educators, writers, artists, and tech enthusiasts who come together to share and celebrate technology. It is a forum to showcase innovation across multiple creative platforms, including engineering and art. By 2014, this event had spread globally, and at least 130 independently sponsored Maker Faires and mini Maker Faires have been held in places like Tokyo, Sweden, and Rome. This technological expo also expanded across the United States, with Faires in Detroit and New York, among other places. Makers and consumers of technology gather globally to show what they have created and share what they have learned, often making visible ideas and concepts that are out of the ordinary and may change human lives for the better—illustrating, as this phenomenon continues to spread, the enduring desire to meet and conquer the challenges of human existence.

D. Chatman-Riley

Further Reading

- Aigrain, P., and S. Aigrain. 2012. *Sharing: Culture and the Economy in the Internet Age*. Amsterdam: Amsterdam University Press.
- Boulton, J. 2014. *100 Ideas That Changed the Web*. London: Laurence King.
- Earley, J., L. Mastny, and A. McKeown. 2009. *Red, White, and Green: Transforming U.S. Biofuels*. Washington, D.C.: Worldwatch Institute.
- “History of the Electric Car.” n.d. <http://energy.gov/articles/history-electric-car>, accessed August 30, 2018.
- Kloski, L., and N. Kloski. 2016. *Getting Started with 3d Printing: A Hands-on Guide to the Hardware, Software, and Services Behind the New Manufacturing Revolution*. n.p.
- Pavia, W. 2009. “Limewire, Torrents and Other Free Stuff: How Bankers Entered the World of the Teenager.” *The Times* (London, England).
- Postigo, Hector. 2012. *The Digital Rights Movement: The Role of Technology in Subverting Digital Copyright*. Cambridge, MA: MIT Press.
- U.S. Department of Energy. 2014. “Celebrating the Completion of the World’s Largest Concentrating Solar Power Plant.” February 13.

Airplane Deicer

The airplane deicer, invented by Leonard A. Haslim in 1988, significantly improved air travel safety by keeping ice off airplane wings, not only in cold weather, but as airplanes fly at cruising altitude, where the air is cold, thin, and low pressure.

As airplanes climb to cruising altitude at about 35,000 feet, the increased speed of the aircraft combined with the low air temperature results in the formation of ice on the wings. This makes the control surfaces such as flaps and ailerons to become immobile, making it impossible to control the aircraft. Additionally, ice on the wing decreases aircraft performance as it adds weight, creating drag and reducing lift, causing aircraft emergencies and crashes.

Leonard A. Haslim, senior engineer at NASA Ames Research Center, invented a system known as the Electro-Expulsive Separation System (EESS). The EESS consists of an elastic, rubberlike deicer boot on the wing’s leading edge with layers of flexible, conducting copper ribbons that are integrated within the boot. When ice builds up on the wing’s leading edge, an electric current is sent through the conductors, causing them to pulse. The pulse is discharged in less than a millisecond, instantly inducing the conductor pairs to repel each other and explosively expand the slit voids between the conductor layers. The ice is immediately shattered into harmless particles that are removed from the wing. This invention earned him the NASA Inventor of the Year Award in 1988.

The EESS trumped the limitations of other existing deicers. In the case of using bleed air to melt the wing ice, the air bled reduces the engine thrust and also increases fuel consumption. Pneumatic boots work slowly and are useful mostly when there is significant ice buildup on the wing. Additionally, they break the ice into big chunks that are harmful to engines and the airfoils. Thermal deicers, although fairly common, require a huge amount of energy—tens of thousands of watts compared to 600 to 900 watts for the EESS. This means that the EESS has lower operating costs. Combined with its lighter weight, this makes it the most efficient method of deicing aircraft. This system was patented by Ames, who then licensed it to Ice Management Systems Inc.

(IMS) of Temecula, California, which made it commercially available.

In 1995, Richard Olson, the CEO of IMS, introduced the electroexpulsive deicing systems to the private sector, starting with Thompson Ramo Woolridge (TRW), who bought the technology for use on a new line of planes. The latest use for this NASA spin-off technology is on unmanned aerial vehicles (UAVs). UAVs are well known for their lightweight and long-duration flights; thus, the previous solutions for deicing were impractical for them. Electroexpulsive technology with its low power requirement and effectiveness on ice of any thickness makes it the best option for UAVs.

There also many other potential uses for these systems, not only in aerospace systems but also in the automotive sector. For vehicles, the EESS can be modified for windshields, eliminating the need to use ice scrapers. Another potential use is in ship deicing. Moreover, EESS technology can be used for bridge deicing. Electroexpulsive technology might have endless uses; however, extensive research on it is still required.

Martha Njuguna

See also *Vol. 2, Sec. 1:* Wright, Wilbur and Orville; *Vol. 2, Sec. 2:* Airplane; *Vol. 3, Sec. 1:* “Air” Athletic Shoes; National Aeronautics and Space Administration (NASA)

Further Reading

“Breaking the Ice.” 1989. *NASA Spinoff*. <http://adsabs.harvard.edu/abs/1989spin.rept...64>, accessed August 31, 2018.

Amazon Web Services

Amazon Web Services (AWS) is a comprehensive cloud computing platform provided by Amazon.com, which began offering services for Web sites and client-side applications in 2006. Since its establishment, AWS has expanded by taking steps to secure its services, but it has experienced several major service interruptions over the years. AWS is both popular and profitable, and it may alter world business infrastructure.

Some of the most popular AWS services include CloudDrive, which allows users to upload and download

music, videos, documents, and photos with the use of Web-connected computers and devices; CloudSearch, a scalable search service; Dynamo Database, a scalable database service; Elastic Computer Cloud, which functions as a set of virtual machines that can run application programs; ElastiCache, which speeds up dynamic Web applications by alleviating database load; Mechanical Turk, which uses the intelligence of a network of humans to perform tasks that computers are ill-suited to do, including writing product descriptions; RedShift, a petabyte-scale data warehouse service connected to business intelligence tools; and Simple Storage Service, a high-speed, online backup for data and application programs. Amazon.com charges for services based on usage, and the rates vary for each service.

To minimize the effects of outages and to ensure the security of stored data, AWS is spread over several global regions. Central hubs are located in the Eastern United States, Western United States, Brazil, Ireland, Singapore, Japan, and Australia. Each of the central hubs is made up of smaller areas called “availability zones.” In spite of these precautions, AWS experienced several major outages in 2011, 2012, and 2017. Amazon.com boasts about its low AWS start-up and operating costs, and it has attracted a lot of Web site- and technology-related business subscribers. For example, Simple Storage Service alone earned \$1.17 billion in 2014. The next year, it reported a 78 percent increase at \$2.1 billion. In 2015, Amazon.com founder Jeff Bezos described AWS as a \$5 billion-a-year business. Worldwide, AWS has over 1 million customers. Every year, it is expanding into more facets of everyday technology-related services. For example, Netflix relies on AWS to manage and provide its online content, and Spotify uses AWS to quickly provide expanded storage needs to its customers. The number of businesses that rely on AWS is extensive and continually rising. Some of these businesses include Yelp, Comcast, Johnson & Johnson, Pfizer, and Kellogg’s. In 2016, AWS received a \$600 million contract from the Central Intelligence Agency. Critics concerned with national security leaks have issued cautions about the unstable nature of online security.

AWS promises to make it possible for business owners to build a technology infrastructure with a tiny operation team. Besides streamlining the start-up

process, it offers tools that business owners can use to analyze business trends and help them make better-informed business decisions more quickly. In short, AWS may alter the traditional structure of business technology support departments and ultimately the way businesses are run.

Rolando Avila

See also Amazon.com; Facebook; Google

Further Reading

“About AWS.” Amazon Web Services. <https://aws.amazon.com/about-aws/>, accessed August 31, 2018.

Amazon.com

As of 2017, Amazon.com was one of the world’s largest online retailers. Jeff Bezos started the company in a region with a technologically skilled workforce. By selling a handful of products, Bezos grew his company to the point that it boasted a variety of products spanning from A to Z. Expansion and reinvestment stifled profits during the early years, but the company began to skyrocket by the early 2000s. Bezos’s faith in the commercial value of technological innovation has greatly contributed to Amazon’s success.

In the early 1990s, Bezos was vice president of D. E. Shaw, a Wall Street firm. During these years, the popularity of the Internet grew steadily as businesses and homes increasingly connected their computers to the World Wide Web. Businessmen began looking for ways to use the new technology to increase sales. After Bezos read a report that projected a growth of annual Web use of 2,300 percent, he quit his job and set out to build his own online store. In 1994, Bezos drew up a list of 20 products that he believed were ideal for Internet commerce. After narrowing the list down to five items (compact discs, computer software, computer hardware, videos, and books), he started Cadabra (the temporary first name of his new company) in Seattle, Washington. He chose Cadabra’s location based on how it promoted the sale of the items on his list and how he hoped it would fill the company’s technological needs. Seattle was close to a large book distribution center, and it had a large technology-literate workforce.

At Bezos’s instruction, employees built a customer-friendly Web site that offered strong search capabilities for customers who knew exactly what they were looking for and general categories of interest for customers who were just looking for something to purchase. In addition, the site kept track of past purchases and used that information to make product recommendations based on each customer’s interests. The site allowed customers to post product reviews and allowed them to view reviews posted by others. Customers had the opportunity to sign up for e-mail alerts, letting them know when certain products were available for purchase. As a bonus, the site offered a book gift-wrapping option for a small fee. By the summer of 1995, the company (renamed Amazon) was fully online.

During the first few years, books accounted for most of the company’s sales. Amazon kept book prices low by filling orders directly from wholesalers and publishers. Surprisingly, by using this method, Amazon was able to offer over 1 million different titles with only an on-hand inventory of about 2,000 books in Bezos’s garage. Yahoo (a popular Web portal) listed Amazon on its “What’s Cool” list, and Netscape (a popular Web browser) listed it on its “What’s New” list. The promotion led to greater book sales. By 1996, Bezos’s garage was too small to keep up with the worldwide demand, so he drew up expansion plans. Amazon’s greatest advantage was that it could offer a much wider variety of products than most brick-and-mortar stores. Amazon’s major drawback, however, was that brick-and-mortar stores could deliver products to customers much faster than online stores could. Consequently, shortening delivery times was a major priority for Amazon, but more capital was needed to put the next step of Bezos’s plan into action.

In 1997 (only two years after Bezos launched the Web site), Amazon became a public company. Bezos used the shareholders’ investments to further expand product offerings and to greatly improve shipping speeds. To accomplish these two major goals, he expanded the Seattle warehouse by 70 percent and opened an East Coast distribution facility in New Castle, Delaware. By increasing the number of on-hand products and by operating two large facilities in different parts of the country, Bezos hoped to offer same-day shipping on 95 percent of all in-stock orders. While competitive prices and the convenience of online



A consumer shops online using Amazon.com. No longer constrained by brick-and-mortar stores that must close at certain hours, online shopping allows consumers to buy whenever the mood strikes. (Tatty/Dreamstime.com)

shopping continued to draw more customers, Amazon's emphasis on good customer service retained many of them. A few months after going public, Amazon became the first Internet retailer to secure 1 million customers. In 1997, Amazon reported \$147.8 million in sales. Just six months later (in 1998), Amazon attracted a million more new customers. By 1998, Amazon became the third-largest bookseller in the United States.

Although Amazon's book sales were huge and growing, Bezos was not content with selling only books. He wanted greater market share, which required investment in continued expansion. To make it easier for customers to navigate through a wider inventory as Amazon added new products, the Web site was organized into product categories (called "stores"). In addition, Bezos believed that technology held great promise in commerce, so he constantly reinvested large portions of Amazon's revenue in technological innovation. These two guiding principles made some investors unhappy, because they preferred immediate profits

rather than long-term reinvestments. In spite of some objections, in 1998 Bezos pressed on with his expansion plan by purchasing Bookpages (the largest online bookseller in the United Kingdom) and Telebook (the largest online bookseller in Germany). The acquisitions gave Amazon much greater access to the European book market. In turn, European books became more accessible in the United States. Bezos also purchased Internet Movie Database (IMDB). IMDB's existing company resources enabled Amazon to easily enter the video download market. That same year, Amazon entered into direct competition with Apple by expanding into the music digital download market. Amazon's new music store of about a quarter of a million songs allowed customers to search for music by artist, song title, or label. Customers were also able to listen to song sound clips to help them decide what to purchase.

In 1999, Amazon expanded into the toy, electronics, tool, and lawn furniture markets. That same year, Amazon's annual sales reached a new high of \$1.6

billion, and *Time* named Bezos the magazine's "Person of the Year." Bezos's determination to keep reinvesting in the company had resulted in seven years of great and continually growing sales, but no profits. Perhaps due to mounting pressure from shareholders, Bezos slightly modified his plan in 2001. He cut costs by laying off 1,300 employees and by closing a distribution facility. That year, Amazon had \$3.12 billion in sales with a \$5 million profit. In 2002, Amazon expanded into the clothing market with retail ties to The Gap and Land's End, and it earned a \$3 million profit—the second annual net profit in the history of the company. Although profits were low compared to sales figures, the fact that Amazon had finally become profitable garnered greater share values and greater public confidence in the future of the company. In 2004, Amazon reached a new high in sales at \$7 billion, and it netted an unprecedented profit of \$588.5 million. In 2008, company sales reached \$19.2 billion with a profit of \$645 million. Even during the recession of 2009, sales reached \$24.5 billion with a profit of \$902 million. Economists credited Amazon sales and profits to the wide variety of products and to its large, loyal customer base.

One of the most popular technological innovations included the Kindle. Although Kindle was not the first e-book reader on the market, innovative features such as its crystal-clear display attracted many consumers. The Kindle generated steady profits, because a demand for Kindles was directly tied to a demand for Amazon digital books. In fact, on Christmas Day 2009, Amazon sold more digital books than printed books. The Kindle Fire (a comparatively low-priced tablet with color display) was Amazon's bestselling product during 2010 Black Friday sales. As the Kindle encouraged digital book sales, the Kindle Fire encouraged Amazon app, music, audiobook, and video sales. Other innovations included Amazon Web Services (AWS), which allowed subscribers to use the computing power of Amazon's servers for Web-related services (including Web design). In an attempt to keep Amazon's large customer base, Bezos introduced Amazon Prime, an annual subscription that gave members free shipping on Amazon products. By 2013, Prime had 16.7 million members.

Before 2010, online shopping was exempt from sales tax in all 50 states. However, since that time,

some states have begun charging sales tax on Amazon purchases. The change resulted in a dip in sales. Consequently, Amazon sought to overturn the tax laws, but it was unsuccessful. In 2013, Bezos announced his plan to use drones to deliver packages to customers' front doors in urban areas within 30 minutes after they had been ordered. However, due to federal rules regulating air travel, as of 2017, the plan was still in the prototype stage. Another concurrent project targeted outer space. Bezos sold an undisclosed amount of his Amazon stock to create and fund Blue Origin, a private aerospace company devoted to manufacturing reusable rocket technology.

Rolando Avila

See also Amazon Web Services; e-Book and e-Reader; *Vol. 3, Sec. 2: Apple*

Further Reading

- Gates, Bill. 2009. "Jeff Bezos." *Time*, May 11, 116–17.
 Quitter, Josh. 2008. "How Jeff Bezos Rules the Retail Space." *Fortune*, May 5, 126.
 Vogelstein, Fred. 2003. "Mighty Amazon." *Fortune*, May 26, 60.
 Zito, Kelly. 1999. "Amazon CEO Tells of Life at the Top." *San Francisco Chronicle*, December 23, B1.

Artificial Memories

Artificial memory is a concept that involves implanting ideas inside an individual's mind, with the expectation of a change in behavior when they awaken.

French scientists are experimenting with animals in hopes of altering their behavior after ingrainings false memories. At France's National Center for Scientific Research, Karim Benchenane and his team are implanting electrodes similar to GPS devices in regions of the brains of mice. Scientists are targeting the medial forebrain bundle and the CA1 region of the hippocampus, which is composed of at least three different cell types that encode the memories needed for spatial navigation. By observing the behavior of the mice and noticing reactions as neurons fire as the animal moves around certain areas, scientists are analyzing their procedures.

These studies allow scientists to understand if cells encode the same kind of information during sleep as they do when the subject is awake. New discoveries also provide further information on the important role that sleeping plays in creating false memories. Psychologist Beth Loftus has proven that memories can be embedded into the mind without the use of advanced technology, as in one recent study, almost three-quarters of the participants reported having clear false memories of a crime they had not committed. By understanding the brain activity associated with the formation of false memories, discoveries in this field can help researchers find ways of preventing memory formations related to stress and sleep deprivation.

Peg A. Lamphier

See also *Vol. 3, Sec. 2: Artificial Intelligence (AI)*

Further Reading

Gundersen, Brigitta. 2015. "Forming Artificial Memories During Sleep." *Nature Neuroscience* 18, no. 4: 483.

Bashen, Janet (1957–)

Janet Bashen is an African American inventor, entrepreneur, and businesswoman. Bashen is the founder and CEO of the Bashen Corporation, a national labor and employment consulting firm that investigates Equal Employment Opportunity (EEO) complaints under Title VII of the 1964 Civil Rights Act. When Bashen determined that an Internet software application was required to add efficiencies to the antiquated paper process used by most organizations at the time, she invented an ingenious Web-based software tool called LinkLine. She invented this software system as a way to file EEO complaints. She is the first African American woman to hold a patent for a piece of software.

Bashen was born on February 12, 1957. She founded her company in 1994, building its foundations in her home at the kitchen table. In 2001, Bashen's company was significantly expanding and she then invented the Web-based software for the EEO filing system,

LinkLine. LinkLine is a Web-based application for EEO claims intake and tracking, claims management, document management, and numerous reports. In 2006, Bashen joined an elite group of African American inventors when her patent was approved.

As an African American businesswoman, Bashen had to be very aggressive to establish solid and immediate credibility with her prospective clients. She had to persuade them that her business was capable of improving the way that EEO fair employment and opportunities investigation services were addressed. Currently, Bashen Corporation has investigated over 34,000 EEO charges and other complaints on behalf of their diverse nationwide clients.

Today, Bashen Corporation has become the preferred firm in the United States for human resources consulting with its EEO compliance consulting services. Bashen has developed successful programs for various organizations, including numerous Fortune 500 companies, health care providers, educational institutions, federal agencies, insurance carriers, financial institutions, and nonprofits. Bashen and her business have received multiple awards. In October 2003, Bashen was given the Pinnacle Award by the Houston Citizens Chamber of Commerce. Bashen is also the recipient of the prestigious Crystal Award presented by the National Association of Negro Business and Professional Women's Clubs Inc., for achievement in business. Bashen is a frequent lecturer on equal employment opportunity and fair employment practices. She has written numerous white papers and articles in the area of EEO, diversity, fair employment practices, and affirmative action.

Katarina M. Ponomaroff

See also *Vol. 1, Sec. 1: Colden, Jane; Glover, Elizabeth; Vol. 1, Sec. 2: Blackwell, Elizabeth; Lowell Mill System*

Further Reading

Holmes, Keith. 2008. *Black Inventors: Crafting Over 200 Years of Success*. Global Black New York: Inventor Research Projects.

Sullivan, Otha Richard, and James Haskins. 2005. *African American Millionaires*. New York: John Wiley & Sons.

Birth Control Patch

The birth control patch, also called the contraceptive patch, can replace a daily birth control pill. Patches are transdermal (applied to the skin) and use estrogen and progestin to prevent egg fertilization. The birth control patch is as reliable as combined birth control pills and is available only by prescription.

Since the first contraceptive came into existence around 3000 BC in ancient Egypt, many inventors have worked to improve contraceptives and birth control over the last 5,000 years. The birth control patch is one such improvement. Invented by Ortho-McNeil Pharmaceutical in 2000, the birth control patch is a small, thin, square, beige patch that looks like a Band-Aid and has a 91 percent effectiveness rate when used correctly. The birth control patch not only provides the benefits of averting pregnancy, but the hormones transmitted through the patch also help with reducing acne, easing painful menstrual cramps, inhibiting bone thinning, limiting iron deficiency anemia, and regulation of one's menstrual cycle, as well as promoting shorter and lighter menstrual periods. The hormones that the birth control patch releases allow cervical mucus to thicken, preventing sperm from reaching and fertilizing eggs. The birth control patch can also inhibit eggs from leaving the ovaries, which is one of the most effective ways to prevent pregnancy.

The birth control patch is waterproof, but it should be applied on dry, clean skin, which allows the hormones to pass from the patch into the bloodstream. The birth control patch has also been known to help with women's sex lives, as they feel more spontaneous by not having to worry whether they took their pill on time. For many women, the patch is preferable to pills because it requires weekly, not daily, attention.

Commercially available since 2002, the birth control patch has made its way into the contraceptive industry by helping women find new ways to control their hormone levels without having to worry about unwelcome pregnancies. With this new form of contraceptive on the market, women can now have more carefree sex live. Although the birth control patch does not protect against sexually transmitted diseases or AIDS, it is a highly recommended birth control that

Planned Parenthood supports and recommends, as it has a low failure rate when used correctly.

Sarah Mae Halpern Weise

See also Vol. 3, Sec. 1: Birth Control Pill

Further Reading

Tucker, Tarvez. 1975. *Birth Control*. New Canaan, CT: Tobey.

Weschler, Toni. 2015. *Taking Charge of Your Fertility, 20th Anniversary Edition: The Definitive Guide to Natural Birth Control, Pregnancy Achievement, and Reproductive Health*. New York: William Morrow Paperbacks.

Blizzard Entertainment

Blizzard Entertainment is a video game development company, most famous for their influential titles *World of Warcraft* (WOW), *Diablo*, and *Starcraft*. It is widely recognized as one of the most successful video game companies in the world.

The company was founded in 1991 as Silicon & Synapse by Allen Adham, Mike Morhaime, and Frank Pearce, three college graduates. Their first titles, *Lost Vikings* and *Rock 'n Roll*, launched on the Super Nintendo and received relatively positive reviews. In 1994, S&S formally changed its name to Blizzard and successfully shipped *Warcraft*, the predecessor to WOW. After the publication of the *Diablo* and *Starcraft* series, Activision purchased Blizzard in 2008, leading to a merger of the two entertainment giants.

As of 2017, against the norm for entertainment companies, Blizzard had achieved and maintained success in all its franchises and planned to host *Destiny 2* on its game client Battle.net later that year. *Overwatch*, *Heroes of the Storm*, *Diablo*, *Starcraft*, *WOW*, and *Hearthstone* had a combined average of 40 million players online each day.

Jacob W. Young

See also Video Game

Further Reading

"Blizzard: Archived Activision Quarterly Results." <https://investor.activision.com/financial-information/quarterly-results>, accessed September 25, 2018.

“Blizzard Timeline.” 2001. February 15. <http://www.blizzard.com/blizz-anniversary/timeline.shtml>, accessed August 31, 2018.

Cancer Research

Cancer research is the study of cancer to discover its causes and to develop methods of treatment, diagnosis, prevention, and possible cures. Cancer research involves various fields of science, including oncology, epidemiology, virology, molecular bioscience, and others. Cancer research also involves performing clinical trials to test the effectiveness of different cancer treatments. Methods of cancer treatment include surgery, chemotherapy, radiation therapy, gene therapy, hormone therapy, immunotherapy, and combined chemo-radiotherapy.

American scientists have made many major discoveries in cancer research. In 1882, William Stewart Halsted, an American surgeon at Johns Hopkins Hospital, was the first to use the radical mastectomy to treat breast cancer. In 1911, Francis Peyton Rous, an American virologist, discovered that cancer can be caused by viruses when he observed that the Rous sarcoma virus (named after him later) caused cancer in chickens. Rous won the 1966 Nobel Prize in Physiology or Medicine for his discovery. In 1941, Charles Brenton Huggins, a Canadian American physiologist at the University of Chicago, discovered that hormones can be used to treat some types of cancer and won the 1966 Nobel Prize in Physiology or Medicine for his work. In 1947, Sidney Farber, an American pediatric pathologist, was able to cause temporary remissions in children suffering from acute leukemia using an antimetabolite drug called aminopterin. Farber is often called the father of modern chemotherapy as a result of his work.

In 1950, Ernst Wynder, an American epidemiologist, and Evarts Ambrose Graham, an American surgeon and physician, helped to show a link between cigarette smoking and lung cancer for the first time. In 1953, Roy Hertz, an American oncologist and endocrinologist, and Min Chiu Li, a Chinese American oncologist, were the first to completely cure a human solid tumor in a patient with choriocarcinoma using the drug methotrexate. In 1958, Emil Jay Freireich, an

American cancer biologist, Emil Frei III, an American oncologist, and James Frederick Holland, an American physician, were the first to use a combination of chemotherapy drugs to cause remissions and increase the survival rate in adults and children with acute leukemia. Freireich, Frei, and Holland were working as researchers at the National Cancer Institute (NCI), and they used a combination of the drugs methotrexate and 6-mercaptopurine to treat acute leukemia, which had been considered incurable until then.

In 1960, Peter Nowell and David Hungerford, American scientists working in Philadelphia, Pennsylvania, were studying the cancer cells of patients with chronic myelogenous leukemia (CML) when they discovered that the cells had an abnormally small chromosome, which was named “the Philadelphia chromosome.” The Philadelphia chromosome is a genetic defect that is linked with CML, because 95 percent of patients with CML have this trait. This discovery was important because, for the first time, cancer was shown to have genetic causes. In 1976, Harold Eliot Varmus, an American cancer biologist, John Michael Bishop, an American immunologist and microbiologist, and Peter K. Vogt, an American molecular biologist, studied the DNA of normal chicken cells and found a gene related to the oncogene of the avian sarcoma virus. An oncogene is a gene that may cause cancer. Their discovery eventually led to the identification of oncogenes in humans. Bishop and Varmus won the 1989 Nobel Prize in Physiology or Medicine for their work.

A number of American organizations are dedicated to cancer research. One major cancer research organization is the National Cancer Institute (NCI). The NCI was founded in 1937 when President Franklin D. Roosevelt passed the National Cancer Act of 1937. In 1971, President Richard Nixon passed the National Cancer Act of 1971, which gave the director of the NCI the authority to develop a national cancer program that encompasses cancer research all over the United States. The NCI operates a nationwide network of 69 NCI-designated Cancer Centers that concentrate on cancer research and treatment. The NCI-designated Cancer Centers consist of 49 comprehensive cancer centers, 13 cancer centers, and 7 basic laboratory cancer centers, nearly all of which are associated with a university. The NCI receives its funding from the U.S.

Congress—more than \$5 billion each year. In fact, the NCI is the world's largest funder of cancer research. The NCI also manages the National Clinical Trials Network and the Developmental Therapeutics Program. One project that the NCI is responsible for is The Cancer Genome Atlas (TCGA), which was started in 2005. TCGA is managed by the NCI's Center for Cancer Genomics and the National Human Genome Research Institute. The purpose of TCGA is to study the genetic factors of cancer by compiling a database of specific genetic mutations that cause cancer, using the techniques of genome sequencing and bioinformatics.

Another American cancer organization is the American Cancer Society (ACS), which was founded in 1913. ACS is a voluntary health organization with a focus on fighting and preventing cancer, and it receives its funding through charitable donations. ACS's goal is to spread cancer awareness and fund cancer research. Some of ACS's donations go toward providing grants to cancer researchers, including 47 researchers that have won Nobel Prizes. ACS also runs a National Cancer Information Center, which is a call center that serves 1 million callers every year. ACS has over 2 million volunteers working for it and has more than 3,400 local offices. Projects organized by ACS include the Relay For Life, a fundraising event, and the Great American Smokeout, which is an annual day dedicated to getting people to quit smoking.

In 2017, the National Cancer Institute received \$5.389 billion from the U.S. Congress. This money is spent on ongoing investigative cancer research and clinical trials that evaluate possible new cancer cures. American scientists are constantly making new discoveries in the pursuit of a cure for this deadly disease. With more funding and research, scientists may one day find the breakthrough discovery that will put an end to cancer once and for all.

Olivia Phan

See also Human Genome Project; *Vol. 3, Sec. 1: Vaccines*; *Vol. 3, Sec. 2: Robotic Surgery*

Further Reading

Choudhry, Hani, and Wei Wu. 2013. *Next Generation Sequencing in Cancer Research, Volume 1:*

Decoding the Cancer Genome. New York: Springer New York.

Greaves, Mel, and Carlo C. Maley. 2016. *Frontiers in Cancer Research: Evolutionary Foundations, Revolutionary Directions.* New York: Springer New York.

Wapner, Jessica. 2014. *The Philadelphia Chromosome: A Genetic Mystery, a Lethal Cancer, and the Improbable Invention of a Lifesaving Treatment.* New York: Workman.

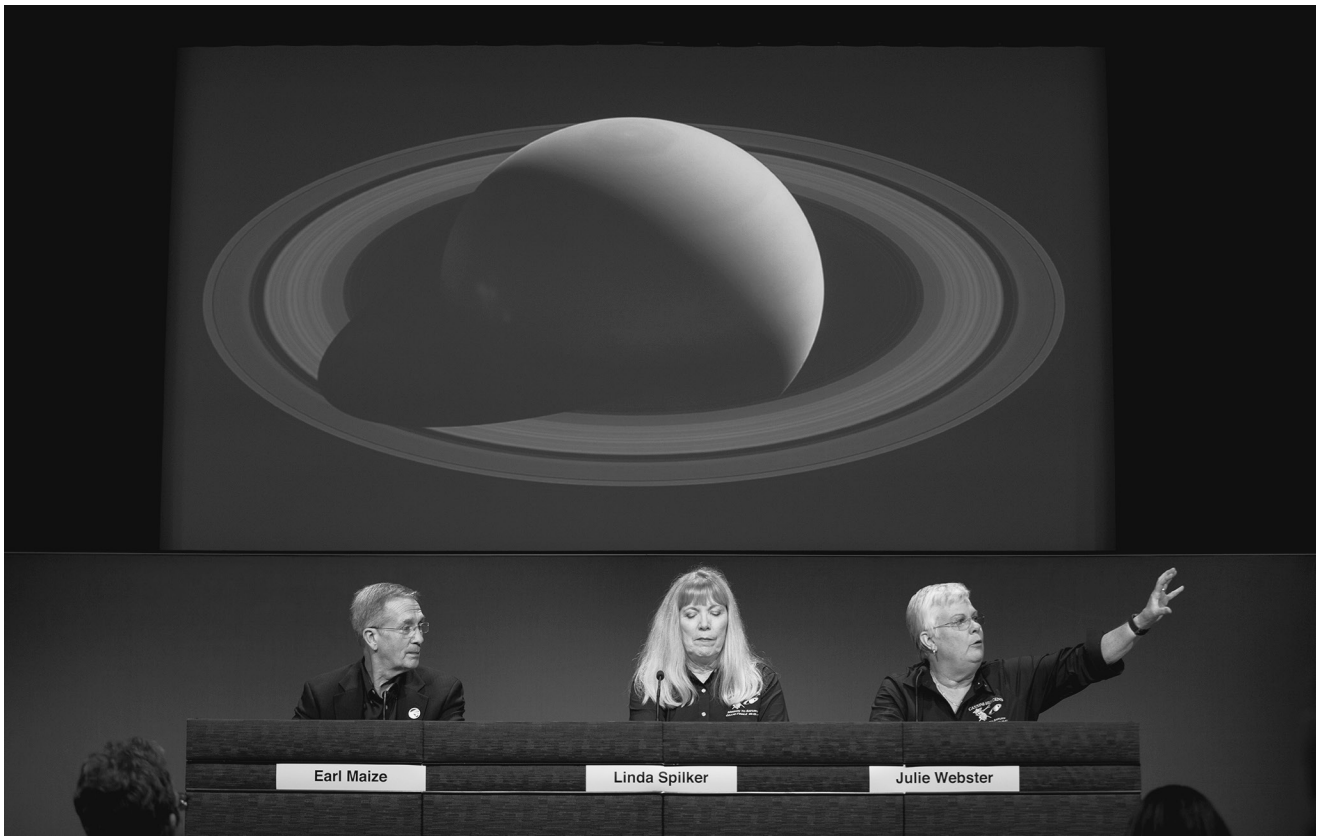
Cassini Saturn Mission

Cassini was launched to explore Saturn, its rings, and its natural satellites on October 15, 1997, by NASA. The data and images taken by Cassini led to numerous discoveries that changed how scientists think about our solar system.

Cassini was the fourth space probe to visit Saturn and the first to enter its orbit. Its mission was meant to last for four years, from June 2004 to May 2008; however, the mission was extended for another two years until September 2010 and was branded the Cassini Equinox Mission. The mission was extended a second and final time with the Cassini Solstice Mission, lasting another seven years until September 15, 2017. On that date, Cassini fell from orbit and burned up in Saturn's upper atmosphere. Overall, Cassini was active in space for almost 20 years, with 13 years spent orbiting Saturn.

Since Cassini began its orbit of Saturn, it obtained 514 gigabytes (GB) of data and also found seven new satellites of Saturn; moreover, Cassini swung by 132 times using Saturn's satellites, and it rotated around Saturn 206 times. It also took 332,000 pictures. Among its discoveries, Cassini found storms on Jupiter and succeeded in supporting the general theory of relativity.

When Cassini swung around Jupiter, scientists measured a frequency shift in the radio waves both to and from the spacecraft as it passed close to the sun. According to the general theory of relativity, a massive object such as the sun causes space-time to curve, which would create a beam from the radio waves. Cassini began a series of radio occultations (events that



Cassini program manager Earl Maize, left, project scientist Linda Spilker, center, and flight director Julie Webster, right, during a press conference following the final plunge of Cassini into Saturn's atmosphere at the Jet Propulsion Laboratory in California, 2017. (Brian van der Brug/Los Angeles Times via Getty Images)

occur when one astronomical object is hidden by another object that passes between it and the observer) to measure the size distribution of particles in Saturn's ring and to measure the atmosphere of Saturn.

When Cassini researched Titan, which is Saturn's moon, it found that Titan has a flow path due to the presence of liquid, allowing scientists to theorize that there could be rain on Titan. Cassini then launched the Huygens probe, a spacecraft sent to search Titan's cloud, atmosphere, and surface in 2005. In 2012, Cassini watched the aftermath of the massive Great White Spot storm that recurs roughly 30 years on Saturn.

Cassini observed the hexagon on the north pole of Saturn for the first time and found two huge polar hurricanes on both its north and south poles. It also found that the hexagon changed from blue to more of a golden color between 2012 and 2016, and there was less blue overall on Saturn between 2004 and 2008.

Cassini's mission ended on September 15, 2017, when its trajectory took it into Saturn's upper

atmosphere and it burned up to prevent any risk of contaminating Saturn's moons, which might have offered habitable environments to stowaway terrestrial microbes on the spacecraft. When Cassini's mission ended, it passed through the gap between Saturn and Saturn's inner rings to maximize the spacecraft's scientific outcome before it was disposed of.

Daichi Kojima

See also Mars Rover Series; *Vol. 3, Sec. 1*: Jet Propulsion Laboratory (JPL); National Aeronautics and Space Administration (NASA)

Further Reading

Lorenz, Ralph, and Jacqueline Mitton. 2002. *Lifting Titan's Veil: Exploring the Giant Moon of Saturn*. Cambridge: Cambridge University Press.

Meltzer, Michael. 2015. *The Cassini-Huygens Visit to Saturn: An Historic Mission to the Ringed Planet*. New York: Springer Praxis Books.

Drake Equation

In 1961, Dr. Frank Drake (1930–) devised the Drake equation, which is a way of estimating the number of communicative extraterrestrial civilizations that may exist in our Milky Way galaxy. Although the equation can be manipulated to a certain extent, it represented the most scientific way of challenging the belief that life on earth was a one-time galactic event. One major legacy of the equation has been a movement to locate radio signals from other planets with the use of innovative technology.

The Drake equation is: $N = R^* \times f_p \times n_e \times f_i \times f_l \times f_c$ $\times L$. N stands for the total number after all of the variables are multiplied. Disagreements over the value of each variable has rendered the value of the equation somewhat subjective. Not surprisingly, those who do not believe that extraterrestrial life exists usually end up with a zero or a very low number for N . In contrast, those who believe that extraterrestrial civilizations exist have determined N to be as high as 5,000. R^* stands for the rate of stars created in our galaxy per year. The National Aeronautics and Space Administration (NASA) calculated this number at six new stars per year.

While some researchers have estimated a higher number for R^* , other researchers have estimated a much lower number. Not all stars have observable planets. Therefore, f_p stands for the fraction of new stars with planets. Based on observations of our solar system, most scientists believe that not all planets are capable of sustaining life. In this respect, n_e stands for the average number of planets that can support life. However, just because a planet can support life, it does not necessarily follow that such a planet contains life. To address this possibility, f_i stands for the fraction of planets that have actually developed life.

Scientists have also observed that not all life forms on earth exhibit intelligence. For this reason, f_l stands for the fraction of planets with life that have developed intelligence. Not all intelligent life forms may have discovered radio waves or may be willing or able to communicate with Earth. Therefore, the fraction of planets with intelligent life willing and able to communicate with Earth is represented by f_c . Finally, even

if a planet contains a thriving civilization, it may be too far away from Earth for its radio waves to reach us. For example, Earth's earliest radio signals have only reached about 100 light years into our galaxy, which is about 100,000 light years in diameter.

Drake founded the first Search for Extraterrestrial Intelligence (SETI) program in 1959. Since that time, various groups, including universities and NASA, have joined the program. Over the years, SETI's desire for better search tools has contributed to the development of innovations in space observation technologies.

Rolando Avila

See also SETI (Search for Extraterrestrial Intelligence); *Vol. 3, Sec. 1*: National Aeronautics and Space Administration (NASA); Space Science and Technology

Further Reading

Vakoch, Douglas A., and Matthew F. Dowd, eds. 2015. *The Drake Equation: Estimating the Prevalence of Extraterrestrial Life through the Ages*. Cambridge: Cambridge University Press.

e-Book and e-Reader

Michael Hart changed the literary world when he created the first electronic book in 1971. Although the concept for e-books was first patented by Ángela Ruiz Robles in 1949, Hart receives credit for developing the first text available for electronic download and distribution. Over the years, the integration of e-books into society has drastically altered the way we write, publish, retain, and share stories and information.

As a student at the University of Illinois, Hart befriended a classmate working in the campus Material Research Lab who allowed him unrestricted access to the lab's large Xerox mainframe computer. Primarily used for processing data, this computer also accessed ARPANET, an early component of the Internet. Hart's first text was the Declaration of Independence, but typed in all caps as the standard computer format dictated. He then delivered a message via ARPANET announcing that a digital copy of the document could now be obtained. It was the first e-book.

With unlimited access to the computer, Hart set to work, striving to reach the goal of digitizing all available public domain information and making it accessible to anyone. After the Declaration of Independence, Hart digitized the Bill of Rights, the U.S. Constitution, and the Bible. He titled his digital endeavor “Project Gutenberg.” Today, Project Gutenberg continues, thanks to the work of volunteers, and touts a collection of over 50,000 free e-books.

Examining the landscape of e-books in today’s technological society, one can easily observe the far reach of Hart’s initiative. With the advancement of handheld reading devices and apps sweeping the globe, the demand and necessity for digitized information continues to grow. The most popular e-reader, the Amazon Kindle, appeared in 2007, and through creative marketing strategies combined with affordable prices, it quickly soared to the top of e-reader sales. Other notable e-reader devices such as Barnes and Noble’s Nook and the Kobo have tried to keep up with the Kindle, but they can’t compete with the dominance that Kindle holds over the entire electronic book phenomenon. As an already established global provider of services, Amazon has attained a prestigious position in the selling of print books, making its success with selling electronic books seamless and simple.

Devices created for the sole purpose of reading face another threat besides other e-reader competitors: tablets. As society becomes more globalized, tablets have asserted themselves as the favored option for electronic reading. Tablets allow consumers access to multiple functions on one device. A user can easily maneuver between a novel, e-mail, the Internet, and social media with the swipe of a finger. This convenience encouraged the once-in-demand e-readers to adapt and funnel efforts into applications downloadable to tablets and other technologies, such as phones and computers.

The United States accepted the new reading platform faster than any other nation, with publishers and technology titans constantly responding with improved products to enhance the reader’s experience. In 2012, e-books ranked as the top format for adult fiction works. The price of an e-book is considerably lower than the price of a printed work, which has helped propel its success. Affordable pricing combined with its

instantaneous arrival after purchase has helped secure e-books’ top position in the literary world. Statistically, more women utilize e-books than men and are the consumer group most likely to purchase an e-book-compatible device. On average, children and teenagers read more e-books than printed books. However, an outlier for this trend lies with elementary readers, who prefer reading a physical book to reading a digital publication.

The effects of e-books and their distribution are varied. With the digitalization of global society, publications reach more audiences than ever before. Interestingly, citizens of many developing countries acquire technology and mobile devices more easily than physical books. Partly responsible for this access is the Worldreader initiative, which provides tablets and e-readers to schools in Africa to assist in education. Before Worldreader, books arrived by boat, and often, by the time they did, interest in and the relevancy of the publications had expired. Providing e-readers to developing countries enables others to take part in the global communication experience. This increased access propels the spread of information as well as the seeking out of education and engagement in local and international entertainment.

One interesting additional point is that most books released electronically are initially published in English. Citizens of countries where English is not the primary language download and read works in English, ultimately establishing it as the global language. However, many traditional cultures, especially in Europe, have resisted the emergence of e-books, feeling that they disregard and diminish cultural and national identities. Historically, countries have documented important events in books, binding and storing them as a type of memorial intended as a catalog of events for future generations. Some fear that the inundation of society with electronic works will eliminate this traditional, meticulous record-keeping practice.

Piracy has also become a major concern. Although authors benefit when more readers access their work, it also increases the risk of their work being downloaded and distributed illegally. For each digital release of a novel, a duplicate copy appears through an alternative online platform for free download just a few days later. Selective release of titles by territory is one motivation

for illegal downloads. Most commonly outside the United States, a title released by Amazon in one country may not become available in a neighboring country until much later, as dictated by territory. Thus, readers opt for alternative methods of acquiring books. Publishers and distributors continue to research the best way to police the illegal distribution of e-books, while many self-publishers argue that piracy is not the problem that traditional publishing says it is. Many independent publishers argue that piracy does not play a large enough part in book distribution to damage authors and that any book, distributed by any means, will eventually improve author sales.

With a digital literary world, opportunities for self-publishing have developed, and more authors now have a chance to spread their work. Due to self-publishing, title production tripled to 235,000 between 2006 and 2012. The accessibility and freedom of self-publishing enables anyone to become an author and offers countless new stories and perspectives to be shared with the world. To assist the growing population of publishers to distribute their work and connect readers with new titles, sites such as Bowker Bookwire have emerged. Established in 2009, Bookwire is a Web site devoted to circulating independently published works along with other major retailers quickly and reliably to make publications available across a variety of platforms.

The success of an e-book relies on two key factors: availability and discoverability. The more exposure and promotion a title receives results in a wider audience, which places greater significance on online reader reviews. As more titles appear online in the same venue as social media, social interactions and evaluations between readers increase. From a tablet, a reader has the ability to highlight portions of the text and share them on various social media platforms or share reviews of a book recently completed, making reading a more social experience. The popular app Goodreads, owned by Amazon, capitalizes on this trend, attracting over 25 million members who share, recommend, and review titles of both e-books and printed works. The ease with which readers can share their insights on stories via the Internet stimulates important discussions and promotes the global exchange of information.

Despite the great advantages e-books present, many speculate on the serious consequences of their development. For instance, because the Internet world moves so quickly, authors feel pressured to produce mediocre work to keep up with the demand of publishers and readers, and they feel their craft is often compromised in the process. Other studies show that the electronic format of literature encourages readers to skim material, absorbing each page in an *F* pattern: beginning at the top, scrolling, reading another section, and scrolling again; reading only portions of a work. This practice results in a lower comprehension of the content and also affects authors and their writing process as they aim to adjust to the trend. Considering the versatility of many e-book-compatible devices, attention spans are also shorter as audiences find themselves distracted by e-mail, games, and social media during their reading. Not only does this affect authors as they strive to create more enticing story lines, but it also affects teachers as they must construct fast-moving and engaging lesson plans to keep students' attention.

Looking forward, readers can anticipate the introduction of video and audio components to their e-books. Authors and publishers hope the added stimuli will enhance the e-book experience, making it more artistic and interactive. The place that e-books currently hold also sets the foundation for growth of international media by increasing sharing and collaboration around the world.

Rebecca Morello

See also Amazon.com; *Vol. 1, Sec. 3: Printing Telegraph*

Further Reading

- Losowsky, A. 2011. "Michael Hart, Inventor of the eBook and Pioneer of Electronic Literacy Has Died." *The Huffington Post*, September 8.
- Portell, G., J. Singer, and L. Tan. 2010. *The E-Reader (r)evolution: Here to Stay or a Path to Digital Process?* Chicago: A. T. Kearney.
- Wischenbart, R. 2013. *Global eBook: A Report on Market Trends and Developments*. Berlin: Ruediger Wischenbart Content and Consulting.

e-Sports

The term “e-sports” refers to electronic sports, which are public presentations of contests involving players of video games rather than the more traditional physical sports such as football or baseball. E-sports have seen a consistent rise in popularity, with different types of video games entering the pool. Popular video games that have contributed largely to the e-sports pool consist of strategy games such as *Starcraft 2*, multiplayer online battle arenas (MOBAs) such as *League of Legends*, *Dota 2*, *Heroes of the Storm*, and *Smite*. First-person shooters such as *Call of Duty*, *Counter Strike: Global Offensive*, and *Overwatch*, as well as fighting games such as *Marvel vs. Capcom*, *Street Fighter*, and *Super Smash Brothers*. The variety of games played in competitive e-sports competitions allows for many spectators to sit and watch their preferred style of game. E-sports has seen a growing popularity in many industries looking for sponsorship opportunities, due to the many viewers worldwide. In 2015, Madison Square Garden was sold out for the *League of Legends* tournament, while 36 million people streamed it online.

E-sports has adapted into conducting many of the same types of personal tournaments, such as against fantasy leagues, to compete with other individuals. These fantasy leagues consist of professionals from different teams, and depending on their performance, the individual scores points against the professionals and can potentially win money. Many companies provide products for those who watch e-sports as well as those who look up to the professionals in their favorite games—products such as aim assist for controllers and glasses to prevent eyestrain from staring at a screen for long periods. These products have seen an increase in sales worldwide due to the popularity of e-sports. Many of the professional teams involved sell their gear online just like any other professional sport teams, such as clothing, peripherals, and even professional jerseys.

New video games are released constantly, and many are designed with a vision toward competitive play. The most recent game added to the e-sports lineup that has gained popularity in the gaming community is

Overwatch. It is based on teams of six people each who work together to break the other team’s defense. Professionals practice for hours every day to improve their reflexes, awareness, game sense, strategies, and personal skills. Just a year after its initial release, the game set up its second world cup in 2017.

Just as in physical sports such as soccer, nations from across the world prepare their best players to compete with other nations. In the 2016 *Overwatch* World Cup, South Korea took the glory after a well-fought battle with Russia. The event had over 100,000 viewers, and the game had only been out for half a year. Its fan base and the number of professional teams that compete in it continue to grow.

Many disagree, however, that e-sports should be considered sports, since they don’t involve physical activity. Professional e-sports players do take part in mental activity and training, and while moving a mouse may not be as physical as running, professionals still run the risk of injuries to their hands for over-extensive play that may be long term and end their careers as well. Certain television channels, such as ESPN, broadcast about e-sports when major tournaments come up. E-sports is a growing competitive sport that may resemble traditional sports but can look very different. Many don’t see chess or poker as sports either.

E-sports teams and audiences have both grown, and a new sports scene can influence the economy as more products are released, and tournament winnings worldwide may influence currency fluctuations. All one needs is an Internet connection and a computer to pick up e-sports as a hobby. Many games allow costume modifications that fans can apply to their favorite characters. If this is a pay option, it boosts the circulation of currency. It can also increase the fan bases for characters.

Many of these games have categories for casual gamers who want to feel the intensity of competitive play, placing them into ranks that match their skill level. Players can practice in the comfort of their own home and potentially become professional e-sports athletes someday. Colleges across the United States have begun offering e-sports scholarships and creating teams to compete nationally and internationally.

The popularity of e-sports in the gaming community has led to streaming of gameplay for casual gamers to learn from and improve their own play. The United States has officially declared all e-sports professionals athletes, allowing them to receive travel visas to enter and compete in the United States without being citizens. This has paved the way for more professional tournaments on U.S. territory, bringing more exposure to the world of e-sports.

Josue Cortez

See also Video Game

Further Reading

Casselman, Ben. 2015. "Resistance Is Futile: eSports Is Massive . . . and Growing." ESPN. May 22. http://www.espn.com/espn/story/_/id/13059210/esports-massive-industry-growing, accessed August 31, 2018.

Schultz, E. J. 2017. "Behind the Rise of Esports and What It Means for Brands." Ad Age. April 3. <http://adage.com/article/news/e-sports/308447/>, accessed August 31, 2018.

Facebook

Facebook is a U.S.-based social networking site built by Mark Zuckerberg from his idea of connecting people via the Internet. Keeping people connected with their friends and family and other things that they want to be connected to, such as information and entertainment, drives the success of this technology. Facebook as a program learns from its users through various algorithms and continuously adapts to fit a larger, diverse, and constantly growing user base. Facebook supports a hacker culture (individuals who enjoy the intellectual challenge of creatively overcoming limitations of software systems to achieve fresh and smart outcomes).

With headquarters at 1 Hacker Way, Menlo Park, California, and additional offices around the United States and the world, the company employed nearly 14,000 people in 2016. Facebook is the largest cohesive source of communication on the globe. There is an average of 1 billion active users on computers and

nearly the same number was on mobile devices daily as of the summer of 2016. With over 80 percent of its daily users outside the North American continent, registered users have made Facebook as a community more heavily populated than any country in the world.

This icon of technology did not come from a high-tech corporation think tank. Instead, Facebook came out of a dorm room and flourished through an Ivy League infancy. Propelled to the public stage on February 4, 2004, from the campus of Harvard University in Cambridge, Massachusetts, Thefacebook.com, an online directory and social networking community, made it possible for Harvard students to create profile pages containing their personal information and to maintain contact with each other. The only requirements were to have an e-mail address ending in "harvard.edu" and to be older than 18 years of age. Labeled "a Mark Zuckerberg production," the contact page listed:

Mark Zuckerberg: Founder, Master and Commander, Enemy of the State

Eduardo Saverin: Business Stuff, Corporate Stuff, Brazilian Affairs

Dustin Moskovitz: No Longer Expendable Programmer, Paid Assassin

Andrew McCollum: Graphic Art, General Rockstar, and

Chris Hughes: The Secret Weapon, as the organizational side of this enterprise.

Mark Zuckerberg (1984–), the founder of Thefacebook.com who would become the CEO of Facebook, was inspired to make Facebook by his experience with another software program called *Facemash* that he had written earlier at Harvard. As founder, Zuckerberg was responsible for setting the general direction and eventually the product strategy for the company. At the inception of Thefacebook.com, Zuckerberg was a computer science major at Harvard University. Cofounder Dustin Moskovitz (1984–) was his roommate and an economics major at Harvard who served as an early spokesperson for the site, as did Chris Hughes (1983–), who had a very useful ability to predict and visualize what the user might need and also served as customer service representative and spin doctor.

Eduardo Saverin (1982–) managed the business development and sales aspects during Facebook's early years. Andrew McCollum (1983–) was enlisted to help with the site's look and was responsible for the original logo of Thefacebook.com: a picture of a young man's face dotted with binary code. Thefacebook.com helped students at Harvard connect with friends and other people they might find interesting. With the ability to create their own profiles and set their own privacy levels, Thefacebook.com was an almost instant success. While there was more personal information displayed on this site than in previous platforms of its type, people nonetheless were intrigued with this new socialization tool.

From its initial launch, Thefacebook.com became popular as an online directory that connected people through social networks at colleges and universities. In March 2004, Thefacebook.com expanded from Harvard to other elite campuses such as Columbia, Stanford, and Yale. By July of this same year, due to its increased popularity and evidence of commercial viability, the headquarters were moved to Palo Alto, California. In September, the "wall" feature was added to the program, and people could now post messages on profiles that everyone could see. By early December, 1 million people were on Thefacebook, and by May 2005, over 800 college networks were a part of Thefacebook community. September 2005 was notable in that shortly after high schools were added as eligible to participate on the site, the "The" was dropped, and the site officially became Facebook.

Six million users were part of Facebook by December of the same year, while 2006 saw the addition of workplace networks and a news feed to the program. It was not until September 26, 2006, that Facebook as we know it began its meteoric rise to icon status, when it opened its doors and allowed anyone to join. By December 2006, there were 12 million users registered and by December 2007, 58 million people had become active on the site.

The year 2008 saw the introduction of the now iconic "Like" button, the launching of a Spanish-language option, and the creation of an app for the Apple iPhone. Facebook has since acquired other programs that support the initial ideal of inclusion and widened its web of connectedness, such as Oculus,

WhatsApp, and perhaps its most visible, profitable, and engaged app, Instagram, in 2012. 2011 saw video calling and the Facebook for iPad come onto the scene. By 2013, over 100 million people per month were verified as using Facebook on their smartphones. And by April 2015, there were over 40 million active small business users.

Facebook users submit details of their history, demographics, personal likes and dislikes, and billions of photos documenting their lives. Due to the copious amounts of information dispensed to the site and the necessity for adequate storage for it, construction was started on a custom data center in Prineville, Oregon, in January 2010, and it opened on April 15, 2011. There followed additional data centers in Altoona, Iowa (2013), and Fort Worth, Texas (2015), as well as an engineering office in Seattle, Washington, in August 2010.

While claiming the dominant space in the social networking arena, Facebook developed and added technology that furthered its mission of connectivity. A fairly recent term, "citizen journalism," has been a staple of Facebook technology. Citizen journalism sites and publications that wish to distribute user-generated information throughout an online community have found fertile ground on Facebook, often through the news feed. Formerly known as EdgeRank, the algorithm decides which stories are important to individual users. News feed stories are personal and informative.

The Facebook Feed Quality Program is based on surveys of tens of thousands of people throughout the world who are asked to rate their experiences with the information they engage with daily on the site. Stories that are highly ranked receive higher spots in the news feed. This type of algorithm, while targeting user "likes," has also been criticized as having the potential to direct and manipulate user behavior and likes and dislikes outside of Facebook. However, according to Facebook, the algorithms decide who sees what, not the humans behind them.

The popularity of this easy-to-use site continued with membership soaring to 600 million users in January 2010. An additional milestone was reached when in August 2015, a record 1 billion people used the site. As of the second quarter of 2016, Facebook had 1.71 billion monthly active users. This popularity has also

led to Facebook becoming a major corporate entity, grossing over \$1.5 billion in profit in the first quarter of 2016. With a board of directors consisting of some of the giants of innovative technology and media, including the CEO of the Bill & Melinda Gates Foundation, chairman and CEO of Netflix, and a president emeritus of the University of North Carolina, Facebook has matured to having a clear and sturdy corporate structure.

Created as part of the Internet, Facebook grew to virtually and seamlessly integrate with sites outside itself but still within the World Wide Web, providing a flexibility and variability of resources that makes it attractive to users across all walks of life. Reportedly, over one-seventh of the world's population and almost half of people with access to an Internet connection utilize Facebook. Facebook is now available in over 70 different languages and can be found on every continent on the planet. Facebook has fundamentally become entrenched in all aspects of American and global culture.

D. Chatman-Riley

See also Vol. 3, Sec. 2: Gates, Bill; Internet

Further Reading

Beahm, George. 2012. *The Boy Billionaire: Mark Zuckerberg in His Own Words (In Their Own Words)*. Chicago: Agate B2.

Good, K. 2013. "From Scrapbook to Facebook: A History of Personal Media Assemblage and Archives." *New Media & Society* 15, no. 4: 557–73.

Kirkpatrick, David. 2011. *The Facebook Effect: The Inside Story of the Company That Is Connecting the World*. New York: Simon & Schuster.

Flight Simulator. See Joystick/Flight Simulator

Gene Patenting

The act of patenting a newly discovered gene allows for unique segments of DNA, which perhaps code for a certain disease or a certain protein, to be owned by

an individual or corporation. In other words, it is the ability to own a gene or gene sequence and the ability to choose what is done with the gene.

The idea of gene patenting is a very controversial subject among physicians and businesses. Most believe it started in 1980 with the trial of *Diamond v. Chakrabarty*, when Ananda Chakrabarty, an Indian microbiologist, created a bacterium that could break down crude oil and desired to patent his creation as a manufactured object. His application was rejected because bacteria are living organisms and therefore cannot be patented. Chakrabarty took the case to the Supreme Court, which ruled in his favor. This case decision was the starting point for gene patenting.

In 1995, Myriad Genetics, wanting to commercialize gene discovery, patented the BRCA1 gene, which is present in all humans but if mutated, it can cause breast or ovarian cancer. After Myriad Genetics obtained the U.S. patent for the BRCA1 gene, the world scrambled to obtain the patent for the other gene involved in these diseases, BRCA2, but in the end, Myriad gained it in 1998.

After obtaining several patents regarding BRCA1 and BRCA2, Myriad sent letters to laboratories around the world, asserting that testing these genes should only be done through either a Myriad laboratory or one that was licensed by the firm. Many countries refused or tried to fight Myriad's control over both patents. The health minister of Ontario spoke out against the patent and publicly refused to honor it. In the United Kingdom, a BRCA2 patent was given to the Cancer Research Campaign, which said that it would not restrict access to the gene.

Myriad still has a strong hold on the patents in the United States and is still the main source of testing for any mutations of these two genes. In May 2009, two groups, the American Civil Liberties Union and the Association for Molecular Pathology, which consists of geneticists, cancer survivors, and pathologists, sued the U.S. Patent and Trademark Office, Myriad, and the University of Utah. Senior Judge Robert W. Sweet ruled that the patents for the genes were invalid on March 29, 2010, saying that a human gene is not an invention. In August 2011, the U.S. Court of Appeals for the Federal Circuit reversed Sweet's decision. On June 13, 2013, the Supreme Court decided that

naturally existing genes and genes sequences cannot be patented. This decision allowed patents for engineered genes, unnatural occurring genes, or complementary DNA (cDNA). Synthetic DNA is made from the molecule that is the framework for making new proteins.

Patenting natural genes has been ruled illegal, yet the patenting of unnatural genes is still a very controversial topic. There are many drawbacks to the idea of gene patenting, but advocates argue there may also be benefits. Gene patenting allows time to investigate new genes, which can lead to breakthroughs. With a patent, a business does not have to worry about competing with others to for discoveries about the patented gene. Gene patenting also encourages more research. The allure of “owning” a certain sequence of genes tends to drive scientists to work harder to obtain such a patent. Gene patents also offer investment opportunities to forward the research of a gene sequence. Gene patenting encourages health competition. It encourages companies to work harder to find cures for diseases so they can profit if another company wants to use that gene. It allows for more open research as companies can bring their findings to the public without the fear of their ideas or research being stolen.

As noted, there are also negatives about gene patenting. It can also slow the progress of research, since the company that owns a certain gene sequence can keep it private, impeding the potential progress from allowing others to study the gene. Patents can also produce monopolies for certain genes. Gene patenting can also slow the appearance of medical results, since samples must be sent only to the company that owns the patent, and the speed of the results returned to the patient depends on that company’s efficiency. Gene patents also raise health care costs because companies that want to use a patented gene must pay for it, driving up prices for everyone.

Rosanne Welch

See also Genetically Modified Foods; *Vol. 3, Sec. 2: Genetic Engineering*

Further Reading

Deegan, R. C. 2008. *Gene Patents*. <https://www.thehastingscenter.org/briefingbook/gene-patents/>.

Ledbetter, D. 2008. “Gene Patenting and Licensing: The Role of Academic Researchers and Advocacy Groups.” *Genetics in Medicine* 10: 314–19.

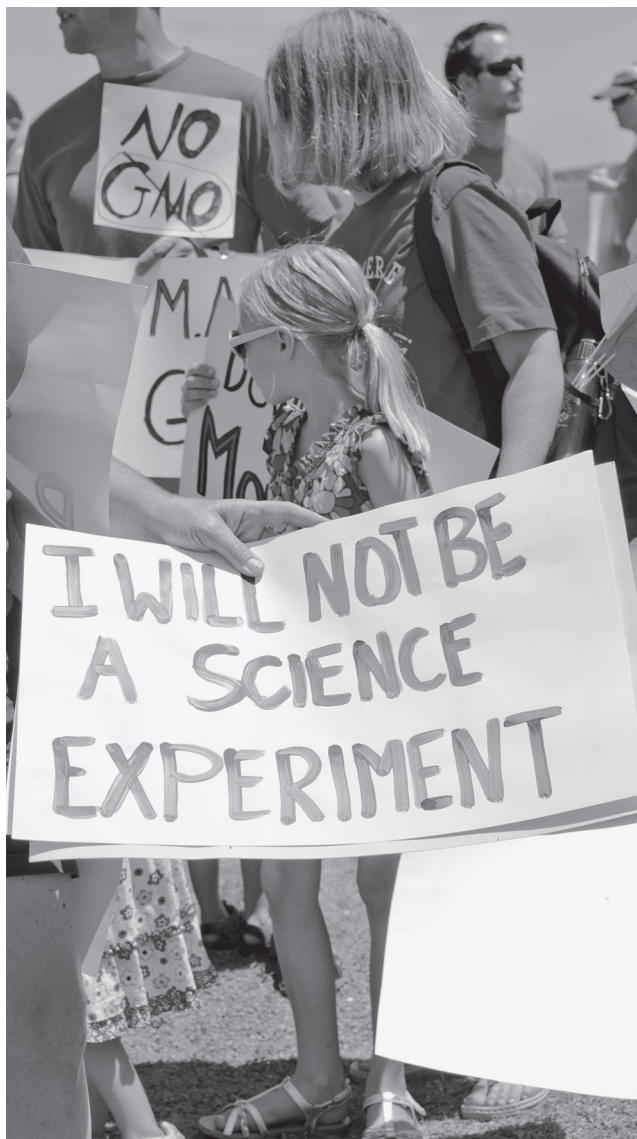
Merz, J. F., and M. K. Cho. 2008. *What are Gene Patents and Why Are People Worried about Them?* January 30. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2220018/>.

Genetically Modified Foods

In 1953, scientists first described the structure of DNA, which contains the patterns for constructing proteins in the body. Drawing on these insights, subsequent generations of molecular biologists experimented with genetic engineering, introducing one or more genes into the genome of a species to create traits that did not naturally occur in that species. They achieved rapid advances in genetic modification of organisms, including food plants, in the 1970s and 1980s, with scientists quickly moving from modifying single cells to manipulating the DNA structures of more complex organisms. In 1972, biochemist Paul Berg created the first recombinant DNA molecules by using enzymes to cut DNA strands and introduce new genes into them. In 1973, biologist Rudolf Jaenisch successfully introduced foreign DNA into a mouse embryo.

The legal status of genetically modified (GM) species (also referred to as genetically modified organisms, or GMOs) was initially unclear. In 1980, General Electric attempted to patent a bacterium capable of breaking down crude oil, which the company believed could be used to clean up oil spills. The federal government rejected the request, claiming that living organisms were not eligible for patent. When GE appealed to the Supreme Court, the Court overturned the patent office’s decision, upholding manufacturers’ right to patent GM species. The first GM plant, an antibiotic-resistant strain of tobacco, was produced in 1982, and field trials for herbicide-resistant tobacco plants occurred in the United States and France in 1986.

Reflecting the rapid advancement of the technology, the 1990s brought the commercial distribution of GM food crops. Calgene, a biotechnology company founded in a California garage in 1980, released in



Parents and children protest in Pensacola, Florida, joining a worldwide effort to raise awareness about Monsanto's impact on the food supply and the dangers of GMOs. (Cheryl Casey/Dreamstime.com)

1994 a modified tomato that possessed a longer shelf life and that ripened without softening. Genetically modified soybeans, cotton, squash, and sugar beets (an alternative to cane sugar) were introduced later in the decade. The most successful early GM crop, "BT corn," contained its own pesticide (*Bacillus thuringiensis*), practically eliminating the need to release toxic sprays across wide swaths of land. "Gold" rice developed in 1999 contained enhanced quantities of vitamin A, designed to address the blindness problems plaguing areas with high rice consumption.

GM crops became subject to extensive government review in the United States, needing approval by the Department of Agriculture, the Food and Drug Administration, and the Environmental Protection Agency before they could be marketed to consumers. However, the United States (in contrast to Mexico, China, most of Europe, and several dozen other countries) does not require explicit labeling of GM products once they are distributed to stores for sale. Though attempts in state legislatures to mandate labeling of GM products have historically been unsuccessful, Connecticut in 2013 and Maine and Vermont in 2014 passed mandatory labeling laws, and new requirements were under consideration in a number of other states. Some prominent American professional organizations, most notably the American Medical Association and the American Association for the Advancement of Science, have argued against mandatory labeling on the grounds that it would needlessly alarm consumers.

Many prominent voices spoke out in favor of GM crops. Foremost among them was former president Jimmy Carter, who established the nonprofit Carter Center after leaving office and set about upon a number of humanitarian ventures, including teaching methods of increasing crop yields to farmers in sub-Saharan Africa. Carter was highly supportive of using genetic engineering to breed plants with improved yields, and strains designed to resist drought were also especially useful in hot tropical countries. Also enthusiastic was biologist Norman Borlaug, who had himself cultivated and developed high-yield, disease-resistant wheat crops in the 1940s and 1950s that improved food security in countries like Mexico, Pakistan, and India. Borlaug was excited about the potential of GM crops as the next step in ending world hunger problems.

Nonetheless, GM foods received criticism on a number of different fronts. The first objection was that more research needed to be conducted before GM foods could be deemed safe for large-scale introduction to already-existing ecosystems. Britain's Prince Charles, for example, argued in 1999 that it was not yet fully understood how GM crops would affect complex, interdependent ecosystems once they became part of them, and that altered genetic material could not be removed from the environment once introduced if some unwanted side effect resulted. Already observers

had noticed that, while BT corn was effectual at killing the pests that antagonized it, it also eliminated many beneficial insects. Furthermore, the process of natural selection meant that over time, insect species would adapt, with the remaining individuals evolving to become pesticide-resistant. What effect would occur once birds ate the insects and the GM material made its way up the food chain was as yet impossible to predict. Bees, too, were likely to cross-pollinate pesticide-resistant crops with unmodified plants in the same area, again with unknown results. The environmental group Greenpeace made a similar argument as Prince Charles, invoking the “precautionary principle” to call for more extensive research on GM crops and to ask the Environmental Protection Agency to suspend approval of BT corn. Some philosophically minded critiques warned of the danger of “playing God” by immorally manipulating genetic material, but proponents replied that genetic engineering was simply an extension of the human modification of the natural world that had been occurring for millennia.

GM foods’ effects on humans themselves also came under scrutiny. One strain of modified rice had been engineered to reduce its levels of glutenin, which made it more suitable for brewing the Japanese rice drink sake. However, the reduction in glutenin unexpectedly encouraged the rice to develop higher levels of compounds called prolamines, which can cause an allergic response in humans. A controversial 1999 study claimed that GM potatoes fed to rats had damaged their digestive tracts, and in 2011, researchers in eastern Quebec found evidence that BT toxins were being passed from human women to fetuses (though proponents pointed to hundreds of other studies showing no negative health effects to humans from eating GM foods and replied to the 1999 study by noting that *any* rat fed solely on potatoes would suffer from protein deficiency as a result).

Another line of criticism involved GM foods’ patentability. Patenting GM products was essential for protecting corporations’ research investments, but it disrupted the normal processes of farming. Since virtually the beginning of human history, farmers had saved a portion of the seeds from each year’s crop to plant the next season. But now farmers had to buy new seed every year from the manufacturer, making GM crops into one of the world’s most profitable commodities.

Monsanto, an agrochemical company that emerged as the leading American producer of GM foods (and which acquired smaller companies like Calgene), compelled farmers buying its seeds to sign contracts allowing the company to test crops in future years to prove that the farmers were not buying one batch of seed and then reproducing the product themselves. Farmers caught violating patent rights in this manner by not buying new seed every year were sued by the hundreds. Monsanto later developed a gene technology known as “the Terminator” that rendered crops sterile, preventing farmers from replanting them without the need for investigations and litigation. The legal protections for GM crops generated broader concerns that only rich, developed nations would be able to afford GM foods, widening the wealth gap between the developed and developing worlds.

Added to this particular concern was the insistence that GM proponent Norman Borlaug’s own innovations themselves, which had produced high-yield wheat cultivars through breeding and natural selection alone, were sufficient to solve the problems of hunger in the 21st century. Ongoing famine problems were not related to a lack of food, critics said, but political instability and widespread corruption in developing nations. GM crops were thus not needed as a solution to world hunger, these analysts claimed, and they accused GM companies of using the famine-reduction justification to shield themselves from criticism of their business practices as well as GM crops’ potentially harmful ecological effects.

Some radical environmental groups like Greenpeace and Friends of the Earth, along with other anti-GM activists, engaged in sporadic acts of vandalism to disrupt research. Activists set the biotechnology laboratory at Michigan State University on fire in 1999, and protestors have vandalized other research sites in the United Kingdom, Australia, and other countries across the world. In May 2013, the “March against Monsanto” movement organized protests in Portland, Oregon; Los Angeles, California; Buenos Aires, Argentina; and other cities.

In spite of these multiple layers and forms of criticism, GM crops encountered no widespread opposition in the United States, and by 2000, they were being sold in grocery stores around the country without

labeling. In 2013, foreign governments that distrusted American corporations, however, opposed the import of GM foods to their countries, and the 2000 Cartagena Protocol signed in Montreal, Canada, required export shipments of food to identify whether or not they contained GM foods and allowed importing countries to reject shipments on that basis alone.

William Michael Camp

See also *Vol. 2, Sec. 1: Food Preservation; Vol. 2, Sec. 3: Freeze-Dried Food*

Further Reading

Lurquin, Paul. 2002. *High Tech Harvest: Understanding Genetically Modified Food Plants*. New York: Westview Press.

Weasel, Lisa. 2009. *Food Fray: Inside the Controversy over Genetically Modification*. New York: AMACOM.

Google

Google began at the nation's greatest technical incubator, Stanford University, as a research project by two PhD students—Larry Page and Sergey Brin. Work on what would become the Google search engine started in 1996. The project was called the Stanford Digital Library Project (SDLP). The project was originally funded by a number of government agencies, including the National Science Foundation. It developed an early search engine called BackRub. It was not the first; in fact, Excite, WebCrawler, Lycos, Infoseek, and OpenText were already on the Internet. Carnegie-Mellon University's Lycos was then the most-used search engine on the browser company Netscape's list, even though Infoseek was the default search engine on Netscape. These early search engines were viewed as software to be licensed or sold, not as moneymaking ventures. The rise of Google was due to its business model rather than its technological advantage.

The history of the search engine is almost as old as the computer itself. The source of commercial search engines can be traced to Stanford University long before Google. The Internet directory Yahoo was formed by two Stanford students, David Filo and Jerry

Yang, in 1994 and was incorporated in 1995 with \$2 million in venture capital. Yahoo functioned as a full-service Internet provider with a search engine licensed from others. Even earlier, a group of Stanford undergraduates had developed a search engine using statistical analysis of word relationships in 1993. The software was released and evolved into the company known as Excite. At the time, no true business model for making money from search engines had emerged except to sell to, license, or develop an Internet service. In many cases, search engines were offered for free by Internet providers. Lycos was a major search engine developed by Carnegie-Mellon University students; it was used freely on the Internet but also developed into a service company. By the late 1990s, new ideas to make money from search engines emerged.

In 1996, AltaVista and Inktomi Corporation were advancing search engine technology. AltaVista was the first to allow for natural-language queries as well as advanced search methods using Boolean logic. Inktomi had a search engine known as Hotwire, which included the best technology and the beginning of a new business model. A great deal of search engine software was available, but the commercial rewards for further development seemed few. Inktomi saw the possibility of commercial gains by charging a flat or recurring fee for commercial Web sites (paid inclusion). While Inktomi pioneered paid inclusion, the market was not yet big enough to support it. Some search engines were using pop-up advertisements with limited success.

In 1998, Bill Gross, founder of Overture (initially known as GoTo.com), developed a pay-per-click business model for his search engine. The idea was that advertisers paid a fee when their Web sites were clicked on after they were found via an Internet search. These agreements are known as sponsored ads. The idea generated a great deal of appeal to advertisers, who were used to broadcast advertising on television. Pay per click assured that members of the audience were being individually targeted. Google would eventually adopt this model and expand its application to targeted audiences. However, the success of Overture initially showed Google and potential investors the possibility of making money with search engines.

In August 1998, Google got a loan from Stanford entrepreneur and cofounder of Sun Microsystems, Andy Bechtolsheim. The next month, the company formally incorporated as Google Inc. and operated out of a garage. The name came from the term “googol,” representing the number 1 followed by 100 zeros. Google quickly gained a reputation as a better search engine than Excite and HotBot. The company moved to the now-famous incubator at 165 University Avenue in Palo Alto. The focus was to build user loyalty and technical superiority. It attracted venture capitalists such as Kleiner Perkins Caufield & Byers and Sequoia Capital. Sequoia had already made profitable investments in Apple Computer, Atari, Oracle, and Cisco. Google was able to get \$25 million from the two, but Sequoia required the hiring of a CEO and a fully developed business model. Sequoia clearly brought the business discipline needed for Google to become dominant. The model was based on selling key search words to advertisers using a combination of bids and click-through charges. Google continued to rise in stature, and eventually America Online chose Google as its search partner, followed quickly by Yahoo. However, it would take another two years for it to fully overcome rivals such as Overture. The competition of search engines led to the incorporation of technology and marketing in Google AdWords.

The unique and specialized advertising model of Google AdWords revolutionized the marketing business model. AdWords is a pay-per-click system that ranks or orders search results for sponsored links. How much the advertiser ultimately pays depends on bidding on per-click rates based on keywords, and on a quality score. The quality score is a complex calculation based on historical click-through rates, relevance of keywords, the advertiser’s account history, and other relevance factors. In addition, Google added location-based targeting and other frequency factors. By 2003, Google had established itself as the dominant search engine and had moved aggressively into other areas. Google went public in 2004 and controlled over 80 percent of worldwide searching. In retrospect, more than any other company, Google commercialized the Internet and took real advertising dollars from other media such as television and radio. The advertising dollars continue to attract new entries into the

search engine market. By 2005, Google had a market value of over \$50 billion. By 2010, even Microsoft had entered the competition with its Bing search engine.

Quentin R. Skrabec

See also Vol. 3, Sec. 1: ARPANET

Further Reading

- Battelle, John. 2005. *The Search: How Google and Its Rivals Rewrote the Rules of Business and Transformed Our Culture*. New York: Portfolio.
- Stross, Randall. 2008. *Planet Google: One Company’s Audacious Plan to Organize Everything We Know*. New York: Free Press.

Google Earth

Commonly referred to as the digital globe, Google Earth is a 3-D representation of Earth constructed with satellite imagery. It was created in 2001 by Keyhole Inc. and obtained by Google in 2004. Since its release, Google Earth has added many features to enhance the digital navigation such as street view and outer space exploration.

Street view allows users to zoom into thousands of cities worldwide. Deep ocean floor areas and celestial bodies can also be observed. This permits one to see the world without the need to travel. Another service that Google Earth has is providing the user with information about certain locations such as landmarks. This feature serves as a guide to explore and understand the planet. Its multifaceted ability attracts a wide range of users because it can be used for fun and entertainment, but it also is a source of knowledge. For example, Google Earth can help students improve their spatial thinking and acquire critical technology skills. While most agree that Google Earth is a useful tool, some claim that it threatens privacy. Despite these allegations, Google Earth continues to innovate its platform and produce new versions.

Leslie Botello

See also Vol. 1, Sec. 1: Rittenhouse, David; Vol. 1, Sec. 3: Solar Compass

Further Reading

Michelson, Dale. 2017. *Google Earth 2017: Learning the Essentials*. n.p.: First Rank.

Summerhayes, Catherine. 2016. *Google Earth: Outreach and Activism*. London: Bloomsbury Academy.

Grandin, Temple (1947–)

Agricultural scientist, spokesperson for autism, and bestselling author, Temple Grandin innovated designs for livestock equipment at feedlots and slaughterhouses. Her system kept the animals calm while producing higher quality meat and reducing accidental deaths and cruelty. She discovered these concepts because her autism made her thinking process different from that of most people. She has written numerous books on both animal behavior and autism.

Temple Grandin was born on August 29, 1947, in Boston, Massachusetts. She was diagnosed with autism at two years old and did not talk until she was four. At the time, autism was considered an infantile schizophrenia caused by a lack of maternal care. The recommended treatment was to put her in a mental institution, which her father, Richard Grandin, supported. Her mother, Eustacia Cutler, disagreed. Her parents divorced, and Cutler sent her daughter to speech therapists, enforced rigid manners at home, and encouraged her to interact with people.

Autism is still not very well understood. It is a genetic disorder that affects the brain's development by forming stronger connections to the brain's analytical centers. At the same time, weaker connections are formed to the brain's social centers. The net effect is that an autistic person may be able to process information at a higher level than a nonautistic person but has poor social skills. Temple Grandin is a visual thinker, but as a young woman, she often misinterpreted social cues.

In 1966, Grandin enrolled in Hampshire Country School in Rindge, New Hampshire, a boarding school for children with special needs. Her science teacher, Bill Carlock, took a special interest in helping her. She then decided to study psychology at Franklin Pierce University so that she could understand people better.

In the summer between high school and college, Grandin lived with her aunt on a ranch in Arizona.

Grandin observed cowboys prodding cattle down an enclosed path into a squeeze chute, a device that restrains a bovine animal between two metal bars. The cattle were distressed as the cowboys prodded them into the chute, but as soon as the chute closed down on the animal, it calmed down instantly. When Grandin started college, she built a machine similar to the cattle chute for herself. With the pull of a lever, two padded panels would clench her sides and hold her. When the university discovered this, it misinterpreted the device as a sexual object and promptly removed it. Grandin wrote a well-researched paper on her results, proving that the device had helped her, and the school allowed her to keep it.

Next, Grandin pursued a master's degree in animal science at Arizona State University. On a field trip to a nearby feedlot, she noticed that the cattle used different kinds of mooing and were sometimes visibly in distress. The cattle tended to injure themselves whenever a handler approached, and a few of them died each week before they could be slaughtered for market. As a result, the feedlot was losing thousands of dollars every week. For her master's project, Grandin decided to explore cattle behavior and figure out how to reduce fear in the livestock.

After graduating from Arizona, Grandin continued to investigate feedlots and slaughterhouses. She published papers in prominent agriculture journals like the *Western Livestock Journal*. Meat-processing companies started to ask her to redesign their operations, and Grandin made a living as a consultant for companies such as McDonald's, Wendy's, and Burger King.

In 1981, Grandin went to a convention hosted by the Autism Society of America. She was the only person there with autism who could easily talk about her experience. As a result, people wanted to hear her speak about autism. Grandin became prominent to the American public when Oliver Sacks wrote about her in his book *An Anthropologist on Mars*. Grandin began to lecture and write books about autism as well as animal behavior.

Temple Grandin now has a PhD in animal science and has written hundreds of scientific papers on livestock handling. She has also written numerous books and articles on autism, and she is often on tour to raise awareness and educate people about different kind of minds. She is currently teaching at Colorado State

University in Fort Collins, Colorado. In 2010, HBO made a biopic about her life titled *Temple Grandin*.

Elliott Popel

See also Hawking, Stephen

Further Reading

Grandin, Temple, and Richard Panek. 2013. *The Autistic Brain: How Different Kinds of Minds Succeed*. New York: Houghton Mifflin.

Temple Grandin. 2010. Directed by Mick Jackson. New York City: HBO Films.

Hawking, Stephen (1942–2018)

Stephen Hawking's brilliance and popularity can easily be identified as nearly equivalent to that of Darwin, Newton, or Einstein. Some of his greatest achievements include a reinterpretation of black holes, analyzing the beginning of time and space, and popularizing science. Hawking presented a theory in 1974 that was so radical, what it described would be later recognized as "Hawking radiation." Hawking argued against the norm and claimed that black holes emitted energy. This point—although seemingly insignificant—brought key concepts of classical and quantum physics together, reshaping the way scientists see the universe. In 1983, Hawking worked with James Hartle to propose yet another theory: that the universe has no physical boundaries. In 1988, Hawking published *A Brief History of Time*, introducing readers to the science behind black holes, the Big Bang, and the rest of his major theories. The book became a worldwide sensation. Offered in 40 different languages, it eventually sold up to 10 million copies.

Stephen Hawking was born on January 8, 1942, in Oxford, England, into a well-educated family. Hawking didn't always excel in his first years of school despite being recognized as its "Einstein." At age 17, he attended the University College, Oxford—his father's alma mater. After three years at Oxford, he was awarded a first-class honors degree, a condition he needed to meet for his future academic work at the University of Cambridge, where he studied cosmology. Though he was seemingly a difficult student, the

examiners who awarded him his degree recognized immediately that Hawking was cleverer than most of them. He fell into depression within the first year of graduate school soon after being diagnosed with amyotrophic lateral sclerosis (ALS). Hawking had lost his sense of purpose, regaining it only with the encouragement of his supervisor, Dennis William Sciama. Hawking's reputation developed after he challenged the work of astronomer Fred Hoyle. In March 1966, he received his degree in applied mathematics and theoretical physics, emphasizing general relativity and cosmology.

In his career, Hawking explored the singularity theorem and developed the second theory of black hole dynamics. In 1973, he started studying quantum gravity and quantum mechanics. As he went along, Hawking regularly engaged in "scientific wagers" (scientific debates) with other scientists. Scientists don't normally achieve celebrity status, especially in their own lifetimes, but Stephen Hawking is one of the handful who have broken that mold. Scientists whose ideas opposed his openly and continuously criticized him, complaining that his status gave him the unfair advantage of "instant credibility."

From 1979 to 2009, Hawking was the Lucasian Chair of Mathematics, a mathematics teaching position at the University of Cambridge, England. This position is recognized as one of the most prestigious academic posts in the world. Its former holders include Isaac Newton and George Stokes. After retiring from his post in 2009, he accepted a Distinguished Research Chair at the Perimeter Institute for Theoretical Physics in Waterloo, Canada. In the same year that he retired, he was awarded the Presidential Medal of Freedom. This is the highest civilian award in the United States.

In 1983, an American physicist by the name of James Hartle developed a proposal with Stephen Hawking at the University of Chicago. Dubbed the "Hartle-Hawking state," this project was carried out to try to explain the beginning stages of the Big Bang theory. It concluded that the universe had no initial boundaries in time or space at all.

In 2017, Hawking warned that humans needed to colonize the moon or another planet within the next 100 years or risk the threat of extinction, shortening his earlier deadline for interplanetary colonization from 1,000 years. He founded his warning on the

dangers from nuclear war, global warming, genetically engineered viruses, and artificial intelligence. In the same year, Hawking criticized the Trump administration for its treatment of government scientists, such as when the U.S. Environmental Protection Agency and Department of Agriculture received orders to remove Web pages from their sites, reportedly even having to submit their reports to Washington for approval. After his open critique, Hawking feared that he would be banned from the United States.

Many believe that Hawking's iconic side has overshadowed the physicist that he really was. In the mass media, nothing said in Hawking's monotonic robot tone was without near-instant credibility. The presumption was that Hawking was an undeniable source of wisdom. Regardless of his genius, he was capable of making mistakes just like any other human being. Plenty of people robbed him of this aspect of his humanity because of his inspiring story. As a whole, society is still uncomfortable with disability and is fascinated with the idea that someone so disabled could be so intelligent.

Since the 1990s, Hawking participated in fundraising activities as a role model for disabled people. In 2014, he accepted the ALS/Ice Bucket challenge but had to have his children take it on his behalf due to his pneumonia.

Karl Terrence D. Molina

See also *Vol. 1, Sec. 1: Astronomical Almanacs*; Rittenhouse, David; *Vol. 2, Sec. 1: Edison, Thomas*; *Vol. 2, Sec. 2: Einstein, Albert*

Further Reading

Hawking, Stephen. 2017. *A Brief History of Time*. New York: Bantam.

Hawking, Stephen, and Simon Prebble. 2001. *The Universe in a Nutshell*. New York: Random House.

White, Michael, and John Gribbin. 2016. *Stephen Hawking: A Life in Science*. London: Pegasus.

Hubble Space Telescope

While earthbound telescopes have helped astronomers investigate the mysteries of the universe since Galileo first used one in 1609, they have all shared a

significant limitation. Telescopes need to penetrate the earth's atmosphere, which interferes with the light coming from distant objects that they attempt to see. A radical 20th-century solution was to place a telescope in low-earth orbit, thus eliminating atmospheric distortion and promising views of the universe vaster and more detailed than any before. The most notable of these was the Hubble Space Telescope (HST), which NASA launched in 1990. Since that time, the HST has become one of NASA's longest missions, and also one of its most successful, returning hundreds of thousands of photographs that have reshaped our understanding of the universe. Most significantly, it has played a critical role in enabling scientists to identify quasars, detect the existence of dark energy, and determine the age of the universe. Hubble has seen galaxies 12 billion light years from Earth, and astronomers refer to this area as the Hubble Ultra Deep Field (HUDF). The telescope is considered to be one of the most productive scientific instruments ever constructed by humankind.

While the HST is the unquestionable champion of orbiting telescopes, it is not unique. One of the first large telescopes was the Orbiting Astronomical Observatory (OAO). Specifically, the observatory's main function was to map and study the emission and absorption characteristics of the sun, stars, planets, and nebulae, along with various interplanetary and interstellar events. Launched in 1968, the total observatory, including its onboard experiments, weighed 4,450 pounds (in contrast, HST weighs 24,490 pounds). Four years later, NASA successfully launched another OAO called Copernicus, and it returned data for over nine years, which was twice as long as the previous orbiting telescope.

After OAO, the next large telescope was the High-Energy Astronomy Observatory (HEAO). The objective of this new class of spacecraft was to locate, identify, and analyze celestial high-energy radiation sources, including pulsars, black holes, neutron stars, and supernovae. There were three HEAO telescopes launched—in 1977, 1978, and 1979.

During this period, NASA began planning for an even more powerful orbiting telescope. This became the Hubble Space Telescope, named after Edwin Hubble (1889–1953), a pioneering American astronomer

most noted for demonstrating that the universe is expanding. At 43 feet in length, it continues to orbit 347 miles above the earth with a velocity of 4.7 miles per second. Goddard Space Flight Center in Greenbelt, Maryland, is the NASA center that manages the mission.

One of the remarkable aspects of the HST is that NASA has been able to service it while in space. Immediately after the HST entered orbit, the first images it sent back were blurry. Scientists discovered that the primary seven-foot mirror had a “spherical aberration” that was just one-fiftieth the width of a piece of paper. NASA planned for nearly a year to send astronauts via a space shuttle to repair it in orbit with complex space walks that riveted the attention of the American public. Though it was one of its most complex missions, it was successful. The space shuttle visited the HST four more times between 1993 and 2009 to make repairs and upgrade its components.

Over 4,000 astronomers and cosmologists have used data from the HST to produce more than 11,000 scholarly articles. Its life span is limited, as the Earth’s gravitational pull will cause it to descend into the atmosphere sometime after 2019.

Since the HST first began operating, NASA has launched other orbiting observatories. In 1995, it launched the Solar & Heliospheric Observatory (SOHO) with a mission to exclusively study our sun. In 1999, the Chandra X-ray Observatory became the most powerful x-ray telescope in the world, enabling astronomers to study gas clouds, particles attracted by black holes, and quasars. In 2003, the Spitzer Space Telescope began focusing on infrared radiation that galaxies, black holes, and comets emit. In 2003, NASA’s Galaxy Evolution Explorer (GALEX) let astronomers investigate the formation of galaxies. Two other space telescopes concentrate on the phenomenon known as gamma ray bursts (GRBs). These are the most powerful known explosions in the universe and are important in better understanding spinning pulsars, black holes, and dark matter. The first of the GRB telescopes launched in 2004 and was named the Swift Gamma Ray Burst Explorer. Four years later, the Fermi Gamma-Ray Space Telescope joined it in orbit. Finally, in 2009, NASA launched the Herschel Space Observatory and the Kepler Mission.

Herschel lets scientists explore the infrared spectrum to look for distant water and the formation of stars. Kepler’s central mission is finding planets similar to Earth within our Milky Way galaxy.

Taken together, the HST and the other space telescopes have resulted in a revolutionary expansion of our knowledge about the universe. Some speculate that humanity has learned more about the universe since the 1970s than in all of history prior to this era combined. There is much more to learn, and the James Webb Space Telescope represents the next generation of orbiting telescopes, with an anticipated launch date in 2018.

Mark D. Bowles

See also Vol. 1, Sec. 3: Mitchell, Maria; Vol. 3, Sec. 1: Apollo Project

Further Reading

- Andersen, Geoff. 2007. *The Telescope: Its History, Technology, and Future*. Princeton, NJ: Princeton University Press.
- Chaisson, Eric. 1998. *The Hubble Wars*. Cambridge, MA: Harvard University Press.
- Leverington, David. 2000. *New Cosmic Horizons: Space Astronomy from the V2 to the Hubble Space Telescope*. Cambridge: Cambridge University Press.
- Zimmerman, Robert. 2008. *The Universe in a Mirror: The Saga of the Hubble Telescope and the Visionaries Who Built It*. Princeton, NJ: Princeton University Press.

Human Genome Project

The Human Genome Project, or HGP, was a research effort to determine the sequence of the human genome and to understand all the genes of human DNA. It was international in scope, involving numerous laboratories and associations of scientists around the world and received public funding from the United States of \$200 million per year via the National Institutes of Health and the Department of Energy. The project formally started in 1990 and finished in 2003. The completion of the Human Genome Project was a huge

milestone in understanding how our genes help determine who we are. The project was largely complete in 2000, when 85 percent of the human genome was decoded, and it ended in 2003 with 99 percent of the genome decoded.

The Human Genome Project opened up many different branches of science, helping us understand different types of diseases, viruses, and mutations in the human body. This alone helps scientists develop more medicines to cure patients. Along with the understanding of the genome, though, the HGP also promoted fear of the power that scientists had with such knowledge.

The HGP officially began in October 1990, but its origins go back to the mid-1980s, when three scientists, Robert Sinsheimer, Renato Dulbecco, and Charles DeLisi, independently came up with the idea of sequencing the entire human genome. Their ideas found supporters in a number of prominent biologists and geneticists. Then, in 1986, committees were established to study the feasibility of a publicly funded project to sequence the human genome. DeLisi outlined a broad plan for the project, and funding eventually enabled it to launch.

The HGP was included in President Reagan's 1988 budget submission and was ultimately approved by Congress. DeLisi had befriended Senator Peter Domenic, chair of the Senate Committee on Energy and Natural Resources, and Congress added a comparable amount to the National Institutes of Health budget.

The Human Genome Project's main goal was to map our genes and sequence only euchromatic regions of the genome—about 90 percent of it. Mapping would eventually reveal the position and spacing of the then-predicted 100,000 genes in each of our cells; sequencing would determine the order of the four base pairs of the nucleotides that compose the DNA molecule: A (adenine), T (thymine), C (cytosine), and G (guanine). While in the process of sequencing the human genome, scientists identified genes for cystic fibrosis, neurofibromatosis, Huntington's disease, and an inherited form of breast cancer.

In addition, the project decoded the genome of the bacterium *E. coli*, a fruit fly, and a nematode worm, to study genetic similarities among species. The HGP team also found out that the human genome has

approximately 3.3 billion base pairs. With the sequence now known, the next step was to identify the genetic variants that increase the risk for common diseases like cancer and diabetes. The key findings were that there are approximately 20,500 genes in human beings, and the same range in mice. Scientists also found that the human genome has significantly more segmental duplications than had been previously suspected. Last, when the draft sequence was published, fewer than 7 percent of protein families appeared to be vertebrate specific.

Since the complete sequencing of human DNA, many controversial topics have arisen about it. With public access to the human genome, many ethical questions presented themselves, such as those about genetic determinism, cloning, and stem cells. Many ethical issues revolve around choosing the genes of offspring. Is it acceptable for parents to handpick genes they would like for their children? The same issue occurs for cloning and stem cells. Some believe that some genes may cause people to sin or commit crimes, or that genes may determine sexuality. One of the worst fears that the HGP brought up was about genetic modification. Scientists were already genetically modifying foods, but the general public has feared that scientists could modify behavior and other things that define us as human.

The Human Genome Project has brought new understanding of the human genetic sequence that makes up who we are. It is described as one of the most significant events in human history—as historical as the moon landing.

Peg A. Lamphier

See also Gene Patenting; *Vol. 2, Sec. 1*: National Institutes of Health (NIH); *Vol. 3, Sec. 1*: Apollo Project

Further Reading

- McElheny, Victor K. 2012. *Drawing the Map of Life: Inside the Human Genome Project*. New York: Basic Books.
- Phua, Kai-Lit. 2004. *Critical Public Health* 14, no. 2 (June): 191–200.
- Zwar, Hub. 2008. *New Genetics & Society* 27, no. 4 (December): 353–76.

Hybrid Vehicles

A hybrid vehicle is any vehicle that utilizes at least two different propulsion systems. Hybrid vehicles can take many forms, from aircraft and watercraft to trains and buses. Power sources can range from something simple, like pedaling, to more complex sources, such as hydrogen-based fuel. However, the most common type of hybrid is the hybrid electric vehicle (HEV) automobile. HEVs still use an internal combustion engine (ICE), but it works alongside an electric motor to achieve greater efficiency while saving fuel costs and reducing damage to the environment.

Contrary to common belief, hybrid vehicles are not new. They have been around for over 100 years. The first hybrid car, called the “Semper Vivus,” was created in 1900 by an Austrian engineer named

Ferdinand Porsche. However, it was not until the 1990s that hybrid cars entered the commercial market. In 1997, the first Toyota Prius was introduced in Japan. Shortly afterward, in 1999, the Honda Insight was released, and it was the first hybrid car available in the United States. The following year, the Toyota Prius went on sale in the United States, and by 2002, there were three different hybrids available.

More companies wanted a piece of the emerging HEV market, so many of the major automakers released their own hybrids, including U.S. manufacturers such as Cadillac, GMC, Chevrolet, Ford, and Honda. HEV sales history reveals a trend that follows gasoline prices. For example, in 2013, the average gas price rose above \$3 per gallon; at the same time, the market share of new hybrid car sales peaked at 3.19 percent. As gasoline prices went down, so did HEV



An electric vehicle charging station near San Francisco's city hall in August 2010. That month the Bay Area Air Quality Management District set aside \$5 million to increase the number of electric car charging stations to 5,000 around the Bay Area. (Justin Sullivan/Getty Images)

sales. The United States has the second-highest level of HEV sales in the world, following Japan. Through 2016, reported sales exceeded 4 million units in the United States alone and over 11 million worldwide.

There are at least three different types of HEVs: plug-in, full, and mild. Although each type has an ICE and an electric motor, their functions differ. Plug-in hybrids, like the Chevy Volt, are the only type that can be charged externally. As the name suggests, they can be plugged into a power source at home or a public charging station. Out of the three types, plug-in hybrids feature the largest battery. They can reach highway speeds and travel tens of miles using only the electric motor. A full hybrid, like the Toyota Prius, has the option to run solely on battery power at lower speeds and distances. They typically have a large battery and motor, along with a sophisticated power-blending system. Mild hybrids, like the Chevrolet Silverado Hybrid, cannot drive solely on the electric motor because it is too weak. Instead, it turns off the ICE and switches to the electric motor in specific situations, like braking, coasting, or idling.

Modern hybrids fuel up with gasoline and are operated just like any other conventional automobile. The HEV system balances energy flow between the ICE and electric motor without any user intervention. To provide the electric motor with sufficient power, hybrids have a large motive battery separate from the auxiliary battery that we see in conventional cars. Usually, the motive battery is based on nickel-metal hydride (NiMH), but newer HEVs are increasingly switching to lithium-ion (Li-ion) batteries. With the exception of the plug-in hybrid, which can be charged by an external source, all HEVs recharge the motive battery in a similar fashion. The primary energy source comes from the ICE, which charges the motive battery whenever it is low. Another key trait is energy regeneration. Anytime the vehicle is in motion and the gas pedal is released, also known as “coasting,” the electric motor captures energy from the momentum. Last but not least, when the brakes are lightly applied, regenerative braking engages to capture additional kinetic energy.

There are several benefits that make hybrids a popular choice. With conventional vehicles, only a fraction of the fuel energy translates into physical movement—in comparison, HEVs are extremely efficient. With hybrids, simply driving downhill will charge the

batteries, and up to 90 percent of the energy in the batteries can be converted into movement. This means that HEVs can be several times more efficient and cheaper to run. Hybrids are also environmentally friendly. Although they run on gasoline, their emissions are substantially lower. In most cases, the HEV’s combustion engine does not need to run when the vehicle is stationary. Conventional vehicles forgo a huge amount of energy during coasting and braking. HEVs, on the other hand, are able to recycle much of this energy by storing it in the batteries. In addition, it has been reported that thanks to regenerative braking, their brake pads last several times longer. Hybrids are known for their outstanding fuel economy, which can benefit entire locations and not just individuals. For example, HEV fuel economy can help island communities to lower their reliance on diesel imports. Certain models, like the 2016 Chevrolet Volt, can get up to 53 miles per gallon.

Hybrid vehicles have their disadvantages. HEVs perform their best in moderate climates, which is probably why they sell the most in places like San Francisco. As for people living in extreme climates, hot or cold, they report decreased performance and loss in range. Another disadvantage is the higher maintenance and repair costs. Private mechanics can offer competitive prices, but they are not always familiar with the hybrid system. If a vehicle breaks down, it may need to be taken to a pricey dealership.

The future of hybrid vehicles looks bright. Fossil fuel is a nonrenewable energy, and despite fluctuating prices, it ultimately goes up in cost. As clean air laws grow stricter, demand for hybrids and other low-emission vehicles is expected to rise. Hybrid technology and components are continuously improving. Currently, lithium-sulfur batteries are being tested. Compared to lithium-ion, lithium-sulfur batteries have superior energy density and can be produced at a much lower cost. When this technology matures, it will be a massive boost for the HEV industry. The battery price has already dropped to \$150 per kilowatt-hour (kWh). A price below \$100 per kWh is believed to be the tipping point where demand for hybrid vehicles will surpass the demand for conventional vehicles.

Ilia D. Petrosan

See also *Vol. 1, Sec. 2: Internal Combustion Engine; Vol. 2, Sec. 1: Duryea, Charles and Frank; Vol. 2, Sec. 2:*

Automobile Technologies (Pre–World War II); Ford, Henry; General Motors (GM); *Vol. 3, Sec. 1: Automotive Technologies* (Post–World War II); Electric Car

Further Reading

- Duffy, James E. 2015. *Modern Automotive Technology*. Tinley Park: Goodheart-Willcox.
- Miller, John M. 2004. *Propulsion Systems for Hybrid Vehicles*. London: The Institution of Engineering and Technology.

Hypertext

Hypertext refers to text that is displayed on electronic devices like computer screens and enables a user to immediately access other informational platforms. Hypertext is used by accessing hyperlinks by touch screen or mouse click. Hypertext allows easy access to large amounts of information on the Internet. In fact, Web pages are written in HTML, which stands for “hypertext markup language.” Hypertext can also give access to the abundance of things like data tables, videos, and images across Web site platforms.

Hypertext connects all of the information available through links enabling the user to navigate through progressive levels of information. Hypertext is typically in one of two forms—either static or dynamic. Static hypertext is constant and has a set platform with concrete formatting. Dynamic hypertext, on the other hand, constantly morphs due to user interaction. This includes progressing levels of intricacy and shifting platforms of information. Both forms have their advantages depending on the type of information being accessed.

The person most often associated with hypertext is American Ted Nelson, who coined the terms “hypermedia” and “hypertext” in 1963. He is considered the visionary behind the modern technology of hypertext used across devices today. Theodore Holm “Ted” Nelson was born on June 17, 1937, in Chicago, Illinois. He is the son of two successful Hollywood parents—movie director Ralph Nelson and actress Celeste Holm. He received a bachelor’s degree from Swarthmore College in 1959. He received a master’s in sociology from Harvard in 1963.

Nelson dreamed about creating a flexible system to access all of the world’s knowledge. His goal was a more accessible database of information that could be easily maneuvered through and cross-referenced. He presented the concept of hypertext in his book *Literary Machines* in 1980, in an overview of the hypertext project Xanadu. Hypertext has revolutionized how we access information every day. The most recognized implementation of hypertext is in the World Wide Web. Nelson’s system of hypertext is of two-way links, which preserves the context of information.

In 2002, Nelson received his doctorate in media and governance from Keio University. In 2010, he published an autobiography called *Possiplex*. Nelson has made many appearances and spoken at major tech conferences. A summary of his work appeared in the film *Lo and Behold* (2016).

Peg A. Lamphier

See also Google; *Vol. 3, Sec. 2: Internet; Personal Computer (PC)*

Further Reading

- Barnet, Belinda. 2014. *Memory Machines: The Evolution of Hypertext*. London: Anthem Press.

International Space Station

The International Space Station (ISS) is a hybrid science, technology, and commerce laboratory in Earth’s orbit. Unlike other space station ventures that were undertaken in competition during the Cold War (1945–1989), the ISS is a product of international cooperation that took place over many years. The desire to scientifically explore the universe with the use of the ISS has also spawned technological innovations.

The idea of habitable space stations originated in 19th-century works of science fiction. For example, in 1869, Reverend Edward Everett Hale envisioned an orbiting “brick moon” capable of sustaining humans in space. In the 20th century, rocket scientist Wernher von Braun popularized a novel design for space stations. Braun believed that humans would need gravity to survive in space, and he proposed creating artificial gravity through the use of a rotating wheel design. By the 1950s, science fiction magazines, books, and

motion pictures portrayed space stations as rotating wheels.

After the Soviet Union launched Sputnik I (the first man-made orbiting satellite) in 1957, the Cold War competition between the Soviet Union and the United States grew to include a space race. In 1969, the United States declared victory in the space race after American astronauts became the first humans to set foot on the moon. Although the Cold War continued for another 20 years, after the U.S. moon landing, the Soviets refocused their space program on creating space stations. The Soviet's first space station, Salyut 1, orbited Earth in 1971. Without artificial gravity, three Soviet cosmonauts in each mission rotation worked for months in a cylindrical space laboratory with a volume half that of the inside of a school bus. In total, the Soviets launched seven successful space stations (with 38 crewed missions) in a span of 11 years. Over this time, the Soviets gained valuable space station-related experience that the U.S. space program lacked. Building on past experiences, during the 1980s, the Soviets develop the Mir, a much larger space station project.

Like Salyut, Skylab (the first American space station) did not employ artificial gravity. In spite of preventive medicine, all American crews combatted nausea the first few days in orbit. However, they eventually assimilated to the weightless environment. Skylab crews conducted many scientific experiments, but their most valuable experiment gauged the effects of weightlessness on the human body. They found that minimizing muscular deterioration by instituting rigorous exercise routines was key to the success of extended manned space missions. After Skylab fell back to Earth in 1979, the American space station program stalled for five years.

In 1984, President Ronald Reagan challenged the National Aeronautics and Space Administration (NASA) to develop a permanently manned space station. Reagan also encouraged NASA to invite other nations to participate in the project. NASA spearheaded the various design initiatives of what became known as Project Freedom. By 1985, the adopted design called for the creation of a central complex (nicknamed the "Power Tower" due to its resemblance to that structure). Trusses also secured the space

station's solar arrays (a group of solar cells designed to capture energy from the sun). The European Space Agency (ESA) agreed to contribute a laboratory module. The Canadian Space Agency (CSA) pledged a mobile robotic system to do work outside the station. The Japan Aerospace Exploration Agency (JAXA), known at that time as the National Space Development Agency, agreed to supply a laboratory module and a cargo module.

As cooperative plans for the "International" space station grew in 1986, the U.S. space shuttle *Challenger* exploded seconds after liftoff. All seven crew members died. The televised *Challenger* disaster had a major influence on Project Freedom. Safety concerns were high, and they led to fewer U.S. shuttle launches and fewer construction-related space walks. In addition, a "lifeboat" was installed to allow crews to quickly evacuate the station in case of possible life-threatening emergencies. These changes increased the time it took to build the station, increased the cost of the project, and ultimately forced a reduction in the size of the station.

The cooperative agreements with other nations required each nation to pay for its own contributions. In the agreement, the United States had assumed the largest share of the cost. During a span of five years, time delays, design changes, and other unforeseen circumstances drove the U.S. portion of the bill from \$8 billion to \$30 billion. American taxpayers and the U.S. Congress began to grow weary of the mounting expense. Fortunately for the project, after the end of the Cold War (1989) and the collapse of the Soviet Union in the early 1990s, President Bill Clinton announced that Russia would also contribute to the project. It was under this new partnership that the project took on a new name: International Space Station Alpha (ISSA). The term "alpha" (first) was included in the name to specify that this was the first international effort to build a space station. However, "alpha" was later dropped from the name, and the shorter "ISS" name caught on.

The new ISS design retained about 75 percent of the Project Freedom design elements. Essentially, the ISS design included a 290-foot-long beam with four wing-like power panels at each end, which generate more energy than what would power 10 average American homes. Over time, a collection of centrally mounted modules was added. The work and living areas

of the station are equivalent to three two-bedroom homes. In 1998, the Russians added Zarya, a core module. The United States then connected two other modules (Unity in 1998 and Destiny in 2001) to the core module. The Russians added the Zvezda module, and the United States added trusses in 2000. Between 2001 and 2002, the Russians added a docking station. During that time, the United States added the Destiny laboratory as well as more trusses and a robotic arm for use outside the station.

By the early 2000s, ISS covered an area of about two football fields. The first ISS crew consisted of two Russians and one American. Later, rotating crews consisting of three to six members were sent from participating nations. In fact, the ISS has been consistently manned since the early 2000s. Construction came to a halt in 2003 after the space shuttle *Columbia* disaster, and it did not resume until 2006. Between 2007 and 2008, the United States added the Harmony node, and the ESA added a laboratory. Between 2008 and 2009, JAXA added Kibo, a Japanese experiment module. The station's trusses were completed in 2009. In 2010, the United States added two observation modules (Tranquility and Cupola), and the Russians added a research module.

The next year, Italy added the Permanent Multipurpose Module (PMM) and the Alpha Magnetic Spectrometer experiment module. In 2011, NASA retired its aging space shuttle fleet. Consequently, the United States relied on Russian Soyuz rockets to transport American astronauts to the station. Other nations, including European nations and Japan, relied on unmanned missions to deliver payloads to the station (with the ESA Automated Transfer Vehicle and the Japanese H-II Transfer Vehicle respectively). All technological equipment eventually wears out (or becomes obsolete as newer technological innovations occur) and must be replaced. The ISS is no exception; parts of it are decades old. Current mission design specs optimistically hope that the ISS will remain in operation until 2028.

Today, the ISS maintains an orbit between 173 and 286 miles above the earth and travels at an average speed of 17,227 miles an hour. ISS flight patterns are well documented, and observers on earth can occasionally catch a glimpse of the station as it zips by overhead. In addition to the cooperation between

spacefaring nations, in recent years, ISS organizers have allowed more people access to the ISS resources by making them remotely available to Earth-based commercial and scientific interests through the use of desktop control stations.

The granting of remote access to the ISS state-of-the-art technologies to Earth's commercial industries has allowed earthbound companies to work from their offices to improve various consumer products. In like manner, the possibilities for academic researchers have expanded dramatically with remote access to the same weightless environment that astronauts work in. In 2017, the official NASA Web page dedicated to providing information on the ISS contained the following motto: "Technology drives exploration." Based on the ISS's history, it could also be said that the desire to explore drives the development of new technologies. Today, the ISS is universally recognized as a world-class facility created by ongoing cooperative technological innovations and capable of producing future technological advancements.

Rolando Avila

See also Vol. 3, Sec. 1: Satellites and Space Probes; Skylab; Space Science and Technology; Voyager Spacecraft; Vol. 3, Sec. 2: Space Shuttle

Further Reading

Catchpole, John E. 2008. *The International Space Station: Building for the Future*. Berlin: Springer.

Rau, Dana Meachen. 2005. *The International Space Station*. Minneapolis: Compass Point Books.

Reference Guide to the International Space Station. 2010. Washington, D.C.: National Aeronautics and Space Administration.

Intraocular Contact Lens

Intraocular contact lenses differ from typical contact lenses in that they are implanted into the eye rather than being attached to the outside. Used for treating cataracts and myopia, these lenses can auto-regulate within the eye, allowing it to focus at different ranges—distance, intermediate, near, and very near. The small, flexible plastic lens is fitted with plastic

side struts that hold it in place within the capsular bag inside the eye once inserted.

Though insertion of the lens by an ocular surgeon involves only a very small incision, thus avoiding the need for stitches, there are some risks associated with such surgery, including infection, lens rotation, inflammation, and the existence of halos around lights seen at nighttime, usually while driving.

The first such lenses were implanted in 1949, but the procedure did not see common use until the late 1990s. The World Health Organization found the number of such surgeries for treatment of cataracts equaled nearly 20 million annually worldwide by 2010.

Monica Orozco

See also Intraocular Contact Lens

Further Reading

Girish Sukhwani, Dinesh Kalra, and Deepak Punjabi. 2013. "Bionic Contact Lens." *International Journal of Students' Research in Technology and Management* 1, no. 1. <http://giapjournals.com/index.php/ijstrtm/article/view/44>, accessed August 31, 2018.

iPod

The iPod is a portable, pocket-sized computer that stores music digitally. Designed and marketed by Apple Inc., the first iteration of the iPod was released on October 23, 2001, about eight months after iTunes was introduced as an interface for purchasing digital music files or subscribing to podcasts. Designed as interdependent products, the iPod and iTunes were created to complement each other. The iPod is an MP3 player, while iTunes provided the sales of music in MP3 format. Apple cofounder Steve Jobs had a team create the company's own digital music player designed to be portable and not too big or too small. Among the 30 people chosen for this project were Tony Fadell and Ben Knauss.

Knauss went over the design flaws of previous player designs and catalogued their glitches while Fadell had the idea of attaching a sale service to the device. The aesthetic design of the iPod was inspired by the circular interface of the 1958 Braun T3

Transistor Radio. In October 2001, Jobs announced that the iPod would be compatible only with Mac computers and that it had 5 gigabytes of space, which could hold approximately 1,000 songs. The software for the iPod was not all completed in-house but in cooperation with another provider.

In July 2002, after requests from the public, Apple finally made the iPod available to Windows users. The third generation of the iPod came in April 2003 with hardware revisions, along with a new dock and another USB 2.0 port to make it easier for PC users to use. The iTunes music store was announced in the summer of 2003. The sale of MP3 files through iTunes eliminated the need for CDs, and it sped up the process of acquiring new music.

Although the introduction of the music store boosted sales of iPods, its battery power and memory size issues prompted customers to ask for a new iPod. The iPod mini was introduced with a 4 GB capacity, and it came in several colors. It was priced at \$249, much less compared to previous iPods. This was because the iPod mini cost about \$70 to make. By the time its fourth generation came along, the iPod had become such a hit that other companies tried to capitalize on the market with their own music players.

By September 2005, the iPod nano was introduced. Designed to mimic the look of hard-drive-based players, it was extremely small. It was available in 2 GB or 4 GB models and came in either black or white. The fifth-generation iPod was announced mere weeks after the nano came out, and it had a whopping 30 GB or 60 GB of space. It could also play videos. The later version had 80 GB of space and a longer battery life.

Apple introduced the iPod shuffle, a small version as small as a binder clip, containing 1 GB of space. The many iterations of the iPod finally led to one of the first smartphones. In January 2007, Jobs announced the iPhone. This device could make phone calls, send texts, surf the Web, and play music, which made the iPod obsolete. An iPhone could also download apps that did all kinds of other things, making it a revolutionary device that put the power of a computer in the palm of one's hand.

John A. Francisco

See also *Vol. 2, Sec. 2:* Radio; *Vol. 3, Sec. 2:* Apple; CD and DVD; Jobs, Steve

Further Reading

- Bull, Michael. 2007. *iPod Culture and Urban Experience*. London: Routledge.
- Leander, Kahney. 2005. *The Cult of iPod*. San Francisco: No Starch Press.
- Levy, Steven. 2006. *The Perfect Thing. How The iPod Shuffles Commerce, Culture, and Coolness*. New York: Simon & Schuster.

Java

Java is a programming language originally released in 1995 by computer scientist James Gosling. It is known as an “object-oriented language.” Such languages easily translate human requests into a form that a computer can understand. Java is seen as one of the most influential computer languages today because it can be easily learned and because it is so effective.

The development of Java began in June 1991 at Sun Microsystems with Gosling and a small team of programmers. One aim of Java was to run programs without the need of a compiler. The compiler is a major function in programming languages that converts code written by programmers into a form that a computer can understand. By removing the need for compilers, Java could theoretically be more applicable to widespread use.

Gosling wanted to make his language as simple and user-friendly as possible. He conducted a mini-experiment where he asked programmers if they knew the underlying workings of certain functions in the C computer language. He found that they did not, so he was inspired to create a simpler language.

To rapidly increase the community of Java programmers, Gosling made the syntax of his language very similar to that of C++; both languages are considered object-oriented. Java also manages its own memory; as a result, it is more user-friendly because there is no worry about memory leaks. However, this prevents the manipulation of some data in all the ways a programmer may desire to. As such, Java is not as

dynamic as C++ when it comes to data management. Despite the differences between these languages, Java is especially easy for programmers familiar with C++ to learn. Gosling stated that it would be more difficult for someone fluent in a programming language other than C++ to learn the syntax of Java.

Java could not meet all of its team’s ideals without making a few compromises. Particular concerns arose about Java’s resource management. Unlike C++, it does not address all fields and may not free all unused resources. This could cause the program to slow dramatically and not function at full capacity. So, Java trades a powerful tool and flexibility for user convenience and simplicity. In addition, the garbage collector implemented in Java is not consistent in performance and may result in positive, negative, or no effects after execution. Of course, no programming language is perfect, and Java is constantly updated to fix deficiencies.

Over time, Java has evolved from being a developer tool to Web tools for running programs on one’s system in embedded applications on the Web. Java has a component called “applets” that allow the user to run applications in a Web browser that supports the Java platform. This is another feature that makes Java a versatile language in its class. Further, a component known as the “servlet” allows the fulfillment of requests by the user to a Web server. This gives a software developer the freedom to create and add substance to the Web.

There are many programming languages available, but Java makes its mark as one of the best-written object-oriented programming languages. Its development team continues to improve the language by fixing bugs and adding useful features. By listening to programmers’ criticism, Java has been able to adapt itself into a very useful language for them. James Gosling has succeeded in his goal of creating a programming language that improves task efficiency, from running programs on our computers, phones, and the Internet to providing security on various networks. Java has become essential in our everyday lives.

Shinha Tsuchida

See also *Vol. 3, Sec. 2:* Ritchie, Dennis

Further Reading

“A Conversation with James Gosling.” <http://www.javaworld.com/article/2076012/core-java/a-conversation-with-james-gosling.html>, accessed August 31, 2018.

Krishnamurthi, Shriram. 2003. *Programming Languages: Application and Interpretation*. Providence, RI: Brown University.

Wexelblat, Richard L. 2014. *History of Programming Languages*. London: Elsevier Science.

Primary Document: Interview with James Gosling, the Creator of Java (2001)

In this interview with James Gosling, the creator of the Java programming language, he describes the philosophy of simplicity that inspired it. He wanted the interface to be as user-friendly as possible and for more people to be able to comprehend the language's functions.

A Conversation with James Gosling The inventor of Java discusses the current state of software

By Bill Venners

JavaWorld Jun 4, 2001 1:00 AM PT

Bill Venners: What have you been up to this past year?

James Gosling: Doing a lot less traveling. I'm not really going around preaching the gospel anymore. Folks are pretty converted these days. I hardly give talks at all now. I've almost exclusively switched over to doing long Q&A sessions where I get up on a stage and either people ask me questions directly, or I pull questions out of a fishbowl. For the last year I've been working at Sun Labs and ignoring all the usual corporate “goo” that comes with working at a company.

I've mostly been working on developer tools. I took a little hacking vacation earlier this year to do a relatively sophisticated Web server. It's just a pile of JavaServer Pages that manage the labs and the corporate document archive. And that has mushroomed features like mad. But my real job has been developing tools. In particular, I'm interested in tools for people who have to write code.

Most developer tools try to shield you from actually writing code in constructing the GUI bits or the database bits. Yet when you do write code you usually get glass teletypes where high tech is keyword coloring. Really high tech gives you a bit of help as you're typing in names, but that's where it ends.

So my work lately has centered on refactoring ideas, where you view a program as an algebraic

structure, and you start doing essentially algebraic transformations on the program. That's been a lot of fun.

Venners: You mean algebraic transformations in the context of refactoring your program?

Gosling: Yeah. One thing my tool will do right now is let you rename a class. Renaming a class at one level is really easy; you just change the name. But how do you change all the references to that class and all the imports? And what about renaming when it includes moving a class from one package to another? I did all this stuff to rederive all the import lists in order to deal with the various naming issues. But it's going even further. This is prototype number three, or maybe number four.

Venners: Will this tool be seen outside of Sun? More than 500 programming languages are available to create our digital world.

Gosling: Yes. If it gets to the state where it looks like it might have even a vague chance of being interesting. My hope is to throw it over the wall some day.

The complexity challenge

Venners: In several recent interviews, you claim that the main challenge for programmers is complexity. Can you elaborate?

Gosling: In some sense, that's what this tool I am building is all about. How do you write a complex application? How do you deal with an application that's a million lines long? How do you even come close to understanding it? How do you make a change to a system like that? How can you cope with it?

Another axis of complexity exists as you lay the application out on a network. One of the things that Java is good at is giving you this homogeneous view of a reality that's usually very heterogeneous. One of the things going gangbusters recently is the cell

phone business. The last time I heard a number, it was like 60,000 Java cell phones were being shipped every day. The numbers have become staggering. And that's not the highest volume Java platform. The highest is actually smart cards, and that's a really big number, although I don't know the exact number.

People building these applications that span the network from edge to center to edge, where you have part of the application in whatever the edge device is—whether it's desktop or cell phone or PDA—some bits and pieces in the infrastructure, and some bits and pieces in the back ends and the databases. One person can work from end to end, but how do you manage the complexity of that?

We don't have really good ways to deal with that issue. We just barely have tools that let us look at what one system is doing and map that across an end-to-end architecture. There are people who have these embedded debuggers for dealing with things like J2ME devices. How do you debug code that's inside your Oracle database? How do you look at the whole thing in totality? That's the hard and interesting problem. The systems being built get more and more complicated every day.

I spent a lot of time a couple of years ago on the whole real-time effort. The motivation for that came entirely from the real-time community. The main issue was that programmers are not writing a few thousand lines of assembly code anymore. These systems are getting really huge. And Java has proven to be pretty successful in building large reliable systems.

Venners: I'm glad I asked that question because I thought you might have been talking more about the complexity of large, monolithic programs.

Gosling: Yes, even isolated things. Some of these isolated applications that sit on one machine are a million lines of code. How do you deal with that? Most people have no way to wrap their head around it. There are all kinds of tools available, from organizational tool you get from object-oriented methodology, to some of the tools that are based on that, like UML modeling.

But of course the more tools you build to cope with such complexity, the more complex things become. We always strain at the limits of our ability to comprehend the artifacts we construct—and that's true for software and for skyscrapers.

Venners: Increasing complexity is also being driven by hardware that's getting cheaper and more powerful.

Gosling: Absolutely. One of my favorite lines is that computers are driven by Moore's Law, which is an exponential process, and human beings are driven by Darwinism.

Venners: And that's a linear process or what?

Gosling: One way to look at it is as a Monte Carlo process. In Monte Carlo algorithms, the precision of the result doubles as you double the amount of time. So you're getting better on a square root kind of a curve, whereas computers are going on a two-to-the-N kind of curve. Their curvature points in opposite directions. How do people with skulls of a limited size deal with that?

The role of simplicity

Venners: The opposite of complexity is simplicity. I have often heard you describe your philosophy when designing Java in the early days: you didn't put something in Java unless five people screamed at you and demanded it. In one interview, you told this really good story about moving to a new apartment and something about keeping things in boxes.

Gosling: That's actually a general principle for life that works really well. When you move to a new apartment, don't unpack. Just sort of move in, and as you need things, pull them out of the boxes. After you've been in the apartment for a couple of months, take the boxes—don't even open them—and just leave what's in there and throw them out.

Venners: The "don't even open them" part is important because it's very hard to throw things away once you know what they are.

Gosling: Right, because if you open them, you say, "oh, I can't part with that."

Venners: So would you say that simplicity is a general philosophy programmers should always have when designing programs?

Gosling: I think in any kind of design, you must drive for simplicity all the time. If you don't, complexity will nail you. Dealing with complexity is hard enough.

In programming language design, one of the standard problems is that the language grows so complex that nobody can understand it. One of the little experiments I tried was asking people about the

rules for unsigned arithmetic in C. It turns out nobody understands how unsigned arithmetic in C works. There are a few obvious things that people understand, but many people don't understand it.

So one of the most important criteria for judging a design for me is the manual. Is the manual out of control, or is it reasonably concise? You can write a

pretty decent Java manual in less than 100 pages. The current Java language spec is pretty thick, but that's because it's probably the most detailed language spec ever written. It goes through all of the details. I couldn't write the Java language spec.

Source: *Java World*, June 4, 2001.

Jemison, Mae (1956–)

In 1992, physician and astronaut Mae Jemison became the first African American woman in space when she worked for the National Aeronautics and Space Administration (NASA) as mission specialist on the space shuttle *Endeavor*.

Born in 1956 to Dorothy Green Jemison, an English and math teacher, and Charlie Jemison, a charity supervisor and carpenter, Jemison had childhood aspirations to travel into space. When she was three years

old, the family moved from Alabama to Chicago. Jemison was inspired by Martin Luther King Jr. to be brave and to cross racial and gender barriers. She also enjoyed watching *Star Trek*, a television show about space travel. The show featured Lt. Uhura, a female communications officer of African descent who appeared in the first episode in 1966 and most episodes afterward.

Jemison graduated from high school in 1973 and was accepted by Stanford University when she was 16 years old. She graduated four years later, a rare black female chemical engineering major. In 1981, Jemison earned her medical degree at Cornell University. She also continued to dance, building on an interest she had first developed in high school.

Once Jemison's medical training finished in 1983, she joined the Peace Corps medical staff and served in West Africa, primarily in Sierra Leone and Liberia. While in Africa, she also worked with the Centers for Disease Control (CDC) on vaccine research. In 1983, the year Jemison went to Africa, Sally Ride became the first American woman astronaut in space. In response, Jemison applied to NASA's space program but was not accepted. Four years later, NASA invited her to reapply. She joined the first astronaut training class after the *Challenger* shuttle explosion in 1986, which had killed all seven of its crew members. In the wake of the disaster, shuttle missions were canceled. In 1988, space shuttle *Discovery* launched, reopening NASA's manned space exploration program.

Jemison's first job at NASA was at the Kennedy Space Center, where she worked in the Shuttle Avionics Integration Laboratory. On September 12, 1992, Jemison was aboard the *Endeavour* as it launched into space as STS-47, Spacelab-J. For eight days, she



Engineer and physician Mae Jemison was the first African American woman in space. She orbited the Earth on the Space Shuttle *Endeavour* in 1992. (NASA)

orbited the earth on the NASA's 50th space shuttle mission. The mission contained a space lab module where astronauts conducted experiments on the effects of microgravity on both materials and living systems. The mission also included the first married astronauts, Jan Davis and Mark C. Lee. STS-47 was also notable for being a mission in cooperation with Japan. As homage to her love of dance, Jemison took a poster for the Alvin Ailey American Dance Theater, a modern dance company based in New York, into space. She also took a picture of Bessie Coleman, the United States' first black woman pilot.

In 1993, Jemison resigned from NASA to better explore the connections between science and the humanities. She founded the Jemison Group to research and market usable, everyday technologies. That same year, she also established the Dorothy Jemison Foundation for excellence. Named for her mother, the not-for-profit organization funds and develops educational programs, teaching methods, and curricula to improve critical thinking and learning by doing. In 1994, the foundation launched The Earth We Share (TEWS), an international science camp program that encourages young people to consider contemporary scientific and environmental issues.

In 1993, Jemison also made her first appearance on television, in a *Star Trek: The Next Generation* episode. She was the first real astronaut to ever appear on *Star Trek*. She has also hosted the Discovery Channel's *World of Wonder*, and in 2006, she appeared in PBS's *African American Lives*.

In 1995, Jemison became a professor in environmental studies at Cornell University and three years later joined First Lady Michelle Obama at a forum for girls in the Washington, D.C., school district. In 1996, Jemison said she had been a victim of police brutality during a routine traffic stop. In both her complaint and in interviews, Jemison said an officer both physically and verbally abused her.

In 2012, the Dorothy Jemison foundation won the bid for the 100 Year Starship Project to create a century-long plan to fund and carry out space travel.

Peg A. Lamphier

See also Vol. 3, Sec. 2: Ride, Sally

Further Reading

Jemison, Mae. 2001. *Find Where the Wind Goes: Moments from My Life*. New York: Scholastic.

Yannuzzi, Della A. 1998. *Mae Jemison: A Space Biography*. Springfield, NJ: Enslow.

Joystick/Flight Simulator

The joystick is the principal controlling device in a cockpit, and it revolutionized the flight simulator industry. All aircraft now have some form of joystick for operation.

The earliest forms of flight simulators were used in 1910, just on the cusp of World War I. These simulators did not rely on wind; they were manually controlled by two people who adjust their altitude levels using pedals while the pilot compensated accordingly. There are multiple reports of the first joystick patents, varying from a U.S. patent in 1926 to a German patent relating to bombers in 1944. By 1960, joysticks were ubiquitous in all flight simulators, which were controlled using radio frequencies.

The joystick is also fundamental in the video game industry, allowing users to easily control characters. Its implementation led to the rise of arcade-style games such as *Pac-Man* and *Dig Dug*. The joystick is now incorporated into most video games today.

Jacob W. Young

See also Video Game

Further Reading

Flight Simulation. 1986. Cambridge: Cambridge University Press.

Kurzweil, Ray (1948–)

Ray Kurzweil is an American author known for many nonfiction publications, revolutionary inventions, and his place in the National Inventors Hall of Fame. His ideas in computer science, the future of technology, and insight on sentience have solidified his name in history as a “future-proof” inventor. His most famous invention is the CCD flatbed scanner.

Kurzweil was born on February 12, 1948, in New York City, and he desired to be an inventor very early in his life. According to several interviews, he built his own robotic game when he was 8 years old and published a paper detailing sensory perception at 14. After pursuing his love for computers in high school, his first company; Kurzweil Computer Products Inc., was founded in 1974. This company helped Kurzweil invent revolutionary machines. Some examples are the aforementioned CCD scanner, a text-to-speech synthesizer, and the Kurzweil reading machine. After the company had much success, it was sold and was eventually owned by Xerox, while Kurzweil quickly moved toward his next project: music.

His next company was founded in 1982 and was known as Kurzweil Music Systems. There, he invented the Kurzweil K250, a machine that synthesized music—another first. After he sold that company in 1990, Kurzweil took to writing and published his first book, *The Age of Spiritual Machines*. Translated into nine different languages, it was a *New York Times* best seller and successfully predicted the future of artificial intelligence for the next decade. His additional publications include *The Singularity Is Near*, *How to Create a Mind: The Secret of Human Thought Revealed*, and *The Age of Intelligent Machines*.

His insight was soon recognized, and he was awarded the National Medal of Technology in 1999 for his inventions from the preceding decade. In 2002, Google offered Kurzweil a position, allowing him to expand on his innovations for the future. He was involved in the creation of the Google Assistant, and using Kurzweil's speech recognition machines, Google successfully launched Google Now. It is continuously improving the software's realism and accuracy.

Kurzweil has been the director of engineering at Google and runs his own Web site that automatically updates with any breakthroughs in science and technology. It averages over 3 million new readers every year. Kurzweil plans to donate his body to science and is researching methods to extend or revive life.

Jacob W. Young

See also Google; Vol. 3, Sec. 1: Xerox Corporation

Further Reading

Kurzweil, R. 1990. *The Age of Intelligent Machines*. Cambridge, MA: MIT Press.

Kurzweil, R. 1999. *The Age of Spiritual Machines: When Computers Exceed Human Intelligence*. New York: Viking.

Linux

Linux (generally pronounced LIH-nuhks) is an operating system designed to provide personal computer users with a free or very low-cost operating system comparable to traditional and usually more expensive Unix systems.

Though Swedish computer science student Linus Torvalds developed Linux in 1991, the system has its roots in a number of American computer science endeavors. In 1969, Ken Thompson and Dennis Richie developed the Unix operating system (OS) while working at AT&T's Bell Laboratories. Not long afterward, they redeveloped Unix to make it more portable. They called this OS "C." This version of Unix became popular with university and business computing systems. In 1983, Richard Stallman, working at the Massachusetts Institute of Technology (MIT), announced the GNU project, which was aimed at using mass collaboration to create free software programs. GNU developed HURD, a multiserver OS, but the software never attracted enough collaborators to become more than an incomplete idea. Nonetheless, the impetus for free operating software (and other kinds of software) had been launched.

In 1991, Linus Torvalds developed the Linux kernel as a Unix-like OS for use in personal computers and other systems. Torvalds wanted to call his software "Freax," a combination of the words "free" and "freak," with the *x* as an homage to Unix. One of the volunteer administrators at Helsinki University thought Freax was a bad name and uploaded it as "Linux," a combination of "Linus" and "Unix." Torvalds thought the name too egotistical, but he eventually agreed to its use. In 1992, Torvalds suggested uploading the Linux kernel under GNU, making it free. He later described this decision as the best he'd ever made. Once Linux was uploaded to GNU,

thousands of programmers worked on the software to expand and improve its operation.

In 1992, computer scientist Andrew Tanenbaum declared Linux obsolete. Tanenbaum said the kernel was too big and not portable enough for modern processors. Most important, he said that because Linux was open source and the product of worldwide collaboration, its largest weakness was that it had no single person or corporation in control. Tanenbaum declared that Linux would be replaced by HURD in the very near future. This prediction proved incorrect, but programmers saw the criticism as a call to modernize Linux.

Over the years, Linux's main OS competition has come from Microsoft, a company whose software programs are most assuredly not free. Commercial software companies see free software as a threat to profit making, though the success of Microsoft would suggest otherwise. Microsoft funded a number of studies to discredit Linux, but as soon as these studies were published, programmers refuted them with studies and papers of their own. In 2009, GNU received 22,000 lines of code from Microsoft, effectively ending the software feud. However altruistic the move to donate code to an open-source, free software platform might have been considered, it appears that Microsoft had been forced to donate the code when a Linux contributor discovered that the company had incorporated GNU software into its own products.

In 2000, the Open Source Development Labs (OSDL), a not-for-profit organization, was established in San Francisco, dedicated to optimizing Linux and developing other free software applications. Seven years later, OSDL merged with the Free Standards Group to establish the Linux Foundation. Linus Torvalds is a foundation fellow. Today, Android tablets, smart watches, and smartphones use Linux-based OSs. While the vast majority of personal computers do not use Linux, 500 of the world's supercomputers do.

Peg A. Lamphier

See also Vol. 3, Sec. 2: Microchip; Open-Source Software; Personal Computer (PC)

Further Reading

Bovet, Daniel P., and Marco Cesati. 2005. *Understanding the Linux Kernel, Third Edition*. Boston: O'Reilly Media.

Molay, Bruce. 2002. *Understanding UNIX/LINUX Programming: A Guide to Theory and Practice*. London: Pearson.

Maker Faire

Maker Faire is described by Maker Media as “the Greatest Show (and Tell) on Earth.” The fair consists of numerous do-it-yourself (DIY) fans who get together several times a year, every year, to showcase their creations to visitors. DIY projects are self-explanatory—most of their materials and tools are often easy to buy locally or online. Since most DIY projects are built at home or privately, very few of them ever become well known or come to the attention of people far away. Maker Faire provides a solution by allowing inventors, hobbyists, crafters, and clubs to exhibit their creations and educate visitors.

“Makers” are part of “the Maker Movement,” a movement that encourages advancements in DIY creation. It includes technological achievements such as in robotics as well as in traditional achievements such as woodworking or sewing. For example, the Luck Dragon project looks like something from the movie *The Neverending Story* and moves around on wheels. At the Faire, arts such as photography, music, and fashion are also welcome. Grow Bucket Life was a kit available for sale at the 2017 San Mateo Maker Faire. It was created by a San Franciscan named Ruth Grace to allow customers to grow plants requiring lots of light in a bucket indoors. The event attracts people of all ages and different backgrounds, so there is a vast variety of visitors and exhibitors alike.

There are two types of Maker Faire: Flagship and Mini. Flagship Maker Faires are large events, with the largest yet held in San Mateo, California, in May 19, 2017, with an attendance of over 150,000 visitors and over 1,300 exhibitors. These Faires are directly sponsored by Maker Media. The best-known Flagships occur in San Mateo and New York, with the San Mateo Maker Faire known as Maker Faire Bay Area and the New York Maker Faire known as the “World Maker Faire.”

Mini Maker Faires, on the other hand, are smaller scale and are run by independent organizers in the

community, working with Maker Media for the fair to run properly. Many of them also occur outside of the United States, reaching as far as Australia, China, and Europe. A third, lesser known type of Maker Faire is a School Maker Faire; a school hosts it, and most of the Makers are students or teachers. These fairs bring attention from the younger generations to the Maker Movement and encourage students from kindergarten to the high school level to try new things and learn more about technology. Knowing that their peers can do something they might have thought was impossible shows them that they can also do it if they try.

Companion pieces to the Faires are the twice-per-month *Make: Magazine* and the DIY kits from Maker Shed. *Make: Magazine* features countless DIY projects and STEM concepts that can be implemented without high-tech tools. Maker Shed's DIY kits teach users about science and procedures for achieving an expected result while acting as a fun learning tool for children and adults. The magazine and the kits were created to teach and were the initial reasons for the creation of the Faire.

The Faire all began with Dale Dougherty, the founder of Maker Media, Maker Faire's parent company. He and Sherry Huss, the vice president of Maker Media, started "the Maker Movement" with Maker Media's creation. After opening two offices in San Francisco and Sebastopol, California, they began *Make: Magazine* to communicate their message to the public. *Make: Magazine* started in January 2005 to publicize DIY projects to its subscribers. Many of the first projects were simple and required items that were easily found at home. As the customer base increased, Maker Media decided to hold their first ever Maker Faire to celebrate the enthusiasm shown by subscribers.

The Faire took place in April 2006 at the fairgrounds of San Mateo, California. It was a huge hit as visitors enjoyed the hands-on activities and learning new skills from demonstrators. The event became annual and soon spread to the rest of the United States, beginning with Texas in 2007. The first ever Mini Maker Faire started in 2009 as a collaboration with the Newcastle Science Fest in Newcastle, United Kingdom. By 2013, Maker Faire was international, with about 100 fairs. Seven were Flagship Maker Faires, and 93 were Mini Maker Faires.

One Maker Faire was even hosted by President Obama at the White House in 2014. This proved to be an important time for the Maker Movement, as the event was called "The Day of Making." That day, several Makers were chosen to share how their lives had been affected by becoming Makers. In 2015, the 10-year anniversary of the Faires, Maker Faire Bay Area was celebrated in San Mateo, with Google acting as a sponsor for the "Learn to Solder" and Goldsmith projects. Over a thousand people visited, with many coming from outside of California. San Mateo, San Francisco, and Oakland even declared that week "Maker Week." It was also the sixth anniversary of the Maker Faire of New York City, and that week was also declared "Maker Week." That same year, 150 fairs occurred globally.

In 2016, Intel and Barnes & Noble joined the list of sponsors for Maker Faire Bay Area along with several others, such as LinkedIn, Roboterra, and Thinglogix acting as sponsors for school attendees. The White House Maker Faire also continued, except that it became a Flagship known as the "National Maker Faire." In 2017, the innovation increased when food became even more integrated with Maker Faire Bay Area with a new section consisting of 15 exhibitors called "Future Food Area."

With the fast rate at which technology is advancing, it is important to keep up. New things are being created or discovered every day, and it can be easy to fall behind. Maker Faire is one way to remain up to date and on track along the road to discovery. The Makers that appear during the Faire know the whats and whys behind their creations and can teach them to visitors. Exhibitors and visitors alike come from all over, some even traveling internationally, so the methods used and exchanged can be rather unusual. There have always been science fairs, but they tend to be competitions that are about who created the best project. The Maker Faire contains ordinary people with extraordinary everyday discoveries.

Since socializing is an important part of human nature, the Maker Faire can play an important role in a young person's life. It is not hard to find someone with a similar mind-set or set of ideals at Maker Faire. It is also easy to find at least one thing that interests or at least amuses you there. From the 3-D drawing pen to

the handmade dolls, there is something for anyone with a hobby. It is also the perfect place for discovering a hobby, since many Makers are hobbyists in their own right. The large variety of demonstrations and products available allows people to try new things and discover something worth investing time and money into. Most Flagship Maker Faires are annually but occur at different times of the year, so they are convenient for many attendees.

Joanne Lee

See also Google; *Vol. 3, Sec. 1*: Intel Corporation

Further Reading

“Impressions from the Largest Maker Faire 2017 in San Mateo.” 2017. *Enterprise Garage Consultancy* (blog). May 21. <http://www.enterprisegarage.io/2017/05/impressions-from-the-largest-maker-faire-2017-in-san-mateo-gallery/>, accessed August 31, 2018.

“Join Us in Our Mission to Empower Makers around the World.” Maker Media. <http://makermedia.com/>, accessed August 31, 2018.

Peppler, Kylie, and Sophia Bender. 2013. “Maker Movement Spreads Innovation One Project at a Time.” 95, no. 3: 22–27.

Pocock, Jennifer. 2016. “Maker Movement 2.0.” *ASEE Prism* 26, no. 3: 34–37.

“Welcome to Maker Faire.” Maker Faire. <http://makerfaire.com/>, accessed August 31, 2018.

March for Science

The March for Science, originally conceived as the Scientists’ March on Washington, took place in over 600 cities in April 2017.

Interest in a pro-science protest stemmed from the 2016 election of Donald Trump. By early 2017, it was clear that Trump’s political appointments to science-related public organizations like the U.S. Environmental Protection Agency (EPA) and the Department of Energy (DOE) would be antiscience, anti-climate change, anti-environment, and against fact-based evidence. March organizers pointed to Trump’s claim that climate change was a hoax perpetrated upon the United

States by China and an administration science advisor’s claim that belief in climate change was cult-like.

Inspired by the January 2017 Women’s March, which had between 3 and 5 million participants worldwide, Science March organizers planned a similar protest. A march announcement that beloved science communicator Bill Nye would lead it only increased the event’s public support.

Marchers, when polled, said their aims for the march were to encourage public officials to make policy decisions based on scientific facts, to oppose political attacks on science and scientists, to protest cuts to science funding, and to promote scientific literacy among Americans.

Emma E. L. Burke

See also Nye, Bill; Tyson, Neil deGrasse

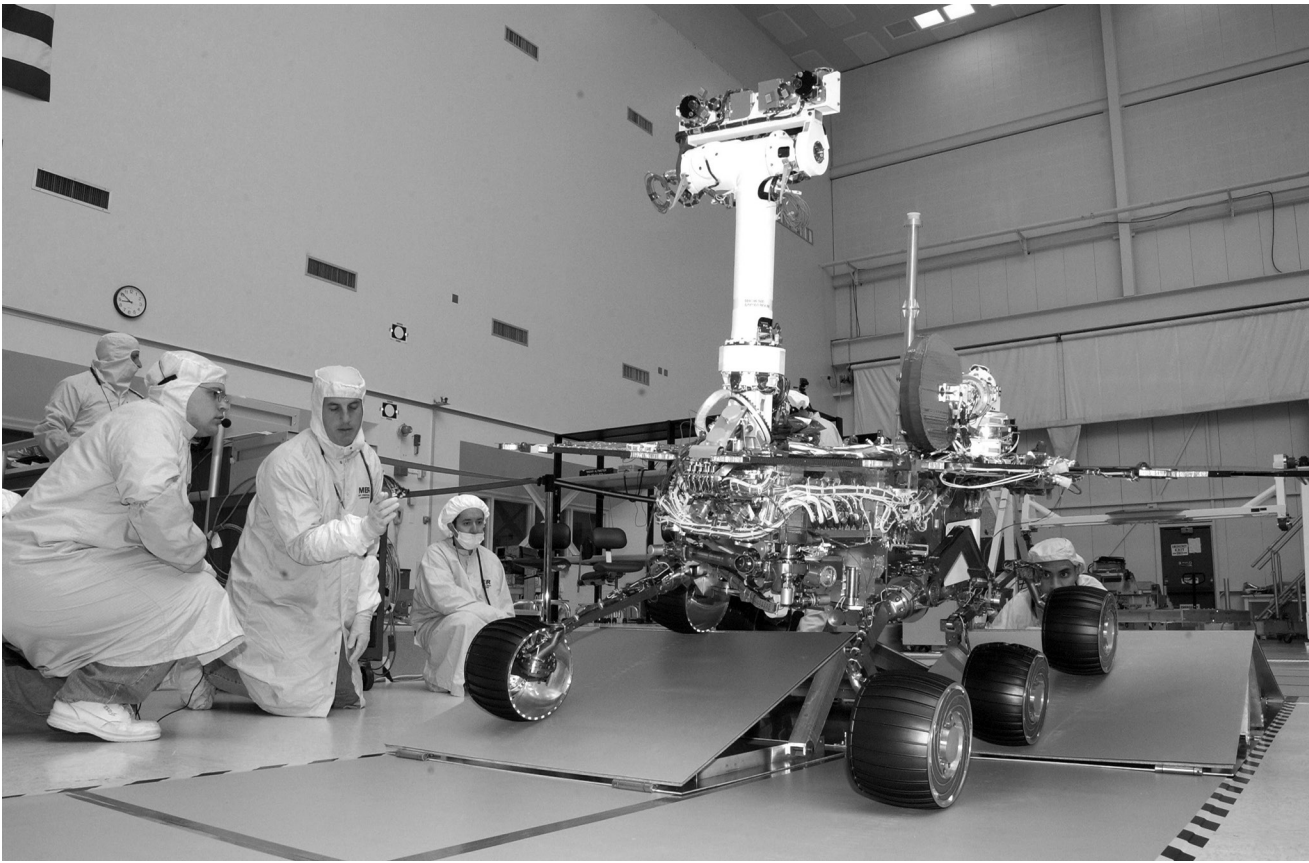
Further Reading

Johnston, David Clay. 2018. *It’s Even Worse Than You Think: What the Trump Administration Is Doing to America*. London: Simon and Schuster.

Mars Rover Series

The Mars rover series includes all rover missions to the planet Mars. A rover is an automated motor vehicle that propels itself across the surface of a planet after landing. Rovers are primarily used to research and characterize the surface of a planet to increase scientific knowledge. Most recently, rover missions to Mars have examined the rocks and soil on the planet to learn about possible past water movement and possible life activity. The Mars rover missions have been led by the U.S. National Aeronautics and Space Administration (NASA), partnered with the Jet Propulsions Laboratory (JPL). The rovers are supplied with instruments to identify and study samples from Mars. For example, the most recent rover, *Opportunity*, contains a miniature thermal emission spectrometer to provide temperature readings of the Mars atmosphere. It also contains an alpha particle x-ray and imager for close-up analysis.

The first space missions to learn more about Mars were planned in the late 1950s. These were mostly



NASA engineers Christopher Voorhees and Brian Harrington test the Mars Exploration Rover B, or *Opportunity*, for mobility. There have been four successful Mars rovers. (NASA/Jet Propulsion Laboratory)

orbiters and landers that never roamed the surface of the planet. However, the early missions did provide an extensive amount of information regarding its atmosphere and surface composition. These early missions directly influenced the success of future rover missions.

There have been four successful rover landings for the United States since NASA created the Mars Exploration Program in 1992. The first successful rover, *Sojourner*, landed on July 4, 1997; however NASA lost communication with it shortly afterward. The second mission, with the rover *Spirit*, landed in 2004; it roamed a total of 4.8 miles, supplying scientists with much information about the planet's rock and soil composition. *Spirit* remained active until its deactivation in 2010 due to being stuck in a sand dune. The third mission, with the still-active Mars rover named *Opportunity*, landed in 2004. The JPL managed the now-defunct *Sojourner*, while NASA continues to operate *Opportunity*.

After *Spirit* found evidence of past water activity, *Opportunity* has tried to gather as many samples as possible to learn more about it. The most recent rover, *Curiosity*, landed on Mars in 2011 and is still operational. JPL and NASA updated this rover with more instruments for examining and analyzing samples. It also has been upgraded to travel faster and farther, with additional heat shields to make it more durable during its mission on Mars. The primary goals of *Spirit* and *Opportunity* are to discover the history of water on Mars and then to determine whether life ever arose on it. The most recent information about past water activity suggests that there is no life currently viable on the surface of the planet.

These last two rover missions have made a lasting impact on space exploration. The evidence of past water activity created a demand for more exploration. There is still much more that NASA and JPL have in store for these rover missions. A new Mars rover is set

to launch in 2020 if there are no difficulties with building it. This mission intends to investigate certain environments on the planet to determine if there is any history of past life. It will have a similar design to *Curiosity* but will include more instruments like drills and sensors that will extract samples and quickly scan for carbon. JPL will be in charge of carrying out the mission if it receives enough funding. Even when the rovers are unable to move, researchers have found ways to continue using them. Regardless of the success of their primary missions, old rovers can still transmit data and act as stationary cameras.

Rosanne Welch

See also Vol. 3, Sec. 1: Jet Propulsion Laboratory (JPL); National Aeronautics and Space Administration (NASA)

Further Reading

- Lakdawalla, Emily. 2018. *The Design and Engineering of Curiosity: How the Mars Rover Performs Its Job*. London: Springer Praxis Books.
- Manning, Rob, and William Simon. 2014. *Mars Rover Curiosity: An Inside Account from Curiosity's Chief Engineer*. Washington, D.C.: Smithsonian Books.

MIDI (Musical Instrument Digital Interface)

Musical Instrument Digital Interface (MIDI) is a way to connect devices that make and control sounds. It connects synthesizers, samplers, and computers using MIDI messages so that they can communicate with each other. This capability enables a keyboard to trigger sounds on another synthesizer, making it possible to record music in a form that grants easy note editing, flexible orchestration, and song arrangement.

MIDI first appeared in 1982 as a compromise among manufacturers and developers of electronic musical instruments to include a common set of hardware connectors and digital codes in their instrument design. In 1983, the MIDI 1.0 Specification was released by the International MIDI Association while music-oriented corporations such as Roland, Yamaha,

Korg, Kawai, and Sequential Circuits all came out with MIDI-capable instruments that year. The idea for MIDI actually dates back to 1978, when Dave Smith, an engineer and synthesizer designer, put out one of the earliest musical instruments to include a microprocessor, the Prophet 5.

The Prophet 5's efficiency was its key feature, as it allowed a sufficient amount of information to be transmitted using only a small amount of data, which ensured that the reproduction of musical timing was acceptably accurate compared to early 1980s digital transmission methods, which had limitations. Although MIDI was popular, it did have some criticisms related to timing issues that resulted in apparent sloppiness in recording and playback. An even more noticeable flaw was the delay between triggering a function via MIDI and the function being carried out, as when sound was reproduced.

It has been over 30 years since the development of MIDI and its revolutionizing of the world of music recording. It allowed synthesizers and drum machines to be connected to computers, an important feature in creating some styles of music. For example, if middle C is struck on a keyboard hooked up to a laptop, MIDI turns all of the information about that note, such as its timbre, length, and volume, into code that can then be changed or manipulated by the computer. In addition, that C can become a D or be dragged out to twice its length. The possibilities are nearly endless. Keyboards aren't the only things that can plug into MIDI. Electric guitars, violins, basses, and more can be played and their sound manipulated. MIDI isn't just used for music; it's also used to control lights and animatronics.

Emma E. L. Burke

See also Vol. 3, Sec. 1: Moog, Robert

Further Reading

- Anderton, Craig. 1986. *MIDI for Musicians*. n.p.: Amsco.
- Droman, David C. 1984. *Exploring MIDI: The Musical Instrument Digital Interface*. n.p.: ComProducts.
- Huber, David Miles. 2007. *The MIDI Manual: A Practical Guide to MIDI in the Project Studio*. London: Taylor & Francis.

Moore, Ann (1934–)

An American nurse, Ann Moore, is credited as the inventor of the Snuggly and Weego child carriers. As a Peace Corps nurse during the 1960s in Togo, West Africa, she noticed that mothers carried their babies in fabric slings. The babies were calm and secure because they were close to their mothers. When Moore returned home and gave birth to her daughter Mandela, she wanted to carry her in the same way. Moore first tried to secure Mandela on her back in the manner she had observed in Africa, but the baby kept slipping. Using a basic backpack and then adapting it to their needs, Moore and her mother designed a carrier that was similar to those used by women in Togo. In this way, the two devised the original soft baby carrier, the Snuggly, as well as other types of specialized carrying cases. Evenflo now makes Moore's child carriers, selling 327,000 units between July 1996 and May 1999. Today, Moore works in the innovation of carrying cases for medical and high-tech instruments.

Eduardo Paz

See also *Vol. 2, Sec. 1*: Knight, Margaret

Further Reading

Satrom, Heather Bruce. 2005. *Innovative Lives: Protecting Precious Cargo, Ann Moore*. Washington, D.C.: National Museum of American History, The Smithsonian.

MP3

"MP3" is the abbreviation of "MPEG-1" or "MPEG-2 Audio Layer III," which is an audio coding format for digital audio. It allows a user to make a duplicate of an original audio file with no appreciable loss of sound quality. MP3 technologies can also facilitate storage of digital files and have become common methods of compressing digital information for transfer and playback on audio players.

The original MP3 technologies were confined to audio engineers who used the technology largely for voice compression. Only later was MP3 technology used for music compression, which allowed for the

development of the iPod and other digital music-streaming technologies. But it is MP3 technology that is largely responsible for the shakeup in the traditional recorded music industry, the proliferation of portable music players and mobile phone music services now available, and the streaming of media content.

Many engineers credit a German graduate student, Karlheinz Brandenburg, as the source of one of the pivotal moments in digital music compression that began in the early 1980s at the University of Erlangen-Nuremberg. One of Brandenburg's professors urged him to work on the problem of how to transmit music over an Integrated Services Digital Network (ISDN) phone line, and Brandenburg began working on his PhD dissertation in audio compression. He realized that transmitting media content over the ISDN line was not just a technical matter; it also depended on how people perceived the quality of music. He used a Suzanne Vega song, "Tom's Diner," as his test product, and he attempted a number of methods to compress the signal without losing audio quality.

Among the major companies that were also experimenting with MP3 technology at the time were Alcatel-Lucent, Microsoft, Bell Labs, and others, but their experiments were not limited to audio alone. Instead, they were focusing on how to compress video and audio for use over telephone lines. But Brandenburg's contributions understood best the need for a high-quality system that replicated original sound quality, and his developments translated to the use of the Internet for distribution.

In 1997, an entrepreneur by the name of Michael Robertson created MP3.com, a Web site that could be used to find free music on the Internet. The company bought 45,000 CDs and loaded them into an internal server for unlimited use by customers; it was quickly sued by the Recording Industry Association of America (RIAA) for copyright infringement and forced to shut down.

Around the same time, Shawn Fanning had the idea in his Northeastern University dorm room that Internet Relay Chat (IRC) protocol could be used as a model for using MP3 technology to share music. He planned to set up a central server that allowed users to connect and share the digital music they had stored on their own computer hard drives. By 1999, he was

working on developing code that allowed peer-to-peer file sharing for the purpose of sharing music, and he called his nascent company Napster. Though Napster was challenged by the RIAA and forced to shut down, so much attention had been given to the downloading and distribution of music that the recorded music industry was forced to radically change its business model.

MP3 technology allowed many companies to compete in the emerging digital music market. Apple used MP3 to develop its iPod media player and the iTunes download service. Other companies also used MP3 to develop their own digital music players, such as Nullsoft's audio player Winamp, developed in 1977, and the first solid-state digital audio player, MPMan, developed by SaeHan Information Systems in Seoul, South Korea, in 1998.

Today, MP3 technology is used for a wide variety of audio devices. Smartphones use it, computers use it, and audio systems in cars use it. Recorded audiobooks on CD are often created with the use of MP3 files, and practically any audio signal over the Internet can use the technology to transfer audio. Over time, the technology has become so refined that it can compress a digital audio signal into a package nearly 1,000 percent smaller than the original, noncompressed sound signal, and it can do so without any loss of sound quality. MP3 technology is largely responsible for the development of streaming services, both audio and video.

Jarice Hanson

See also iPod; *Vol. 2, Sec. 2: Gramophone/Victrola*

Further Reading

Ewing, Jack. 2007. "How MP3 Was Born." *Bloomberg Businessweek*, March 5.

Knopper, Steve. 2009. *Appetite for Self-Destruction: The Spectacular Crash of the Record Industry in the Digital Age*. New York: Free Press.

Negroponte, Nicholas (1943–)

Nicholas Negroponte, an architect and computer scientist, is the founder of One Laptop per Child and cofounder of programs such as the Media Lab at the Massachusetts Institute of Technology (MIT). He is

the author of *Being Digital* and *Unleashing the Killer App: Digital Strategies for Market Dominance*.

Negroponte was born in New York City to Greek immigrants Dimitri John Negroponte and Catherine Coumantaros. He has three brothers: John Negroponte, former U.S. deputy secretary of state; Michael Negroponte, an Emmy Award-winning director; and George Negroponte, an artist who had been named president of the Drawing Center from 2002 to 2007. Negroponte attended multiple schools in his adolescence, including Buckley School in New York, Fay School in Massachusetts, Le Rosey in Switzerland, and Choate (now Choate Rosemary Hall) in Wallingford, Connecticut. He then studied architecture at MIT, where he earned a master's degree in architecture in 1966.

Negroponte began working at MIT in 1966 and taught as a visiting scholar at other universities, including the University of California, Berkeley; Yale; and Michigan State. It was at MIT that Negroponte founded his first organization in 1967 called MIT's Architecture Machine Group. The purpose of this group was to study new approaches to human-computer interaction. He went on to cocreate the MIT Media Lab alongside Jerome B. Wiesner. The MIT Media Lab serves as a workshop for invention and innovation in the fields of technology, multimedia, science, art, and design.

In 1992, Negroponte aided in the development of *Wired* magazine, which focuses on the developing relationship between technology and culture. He has received opposition for his views from other scholars who believe that he fails to consider the consequences of new technology. It is also from his monthly column in *Wired* magazine that he compiled his work for the book *Being Digital*, which was published in 1995.

In *Being Digital*, Negroponte makes predictions about the future of society's relationship with technology. The phrase "Negroponte Switch" originated from the book and refers to his prediction of the switch from receiving and sending information using cables to doing so using airwaves. He also predicted that touch screens and voice recognition software would develop and replace the mouse and pointer in interactive technology. He has appeared to be accurate, as smartphones and tablets use these methods. He has been

labeled as a “digital optimist” for believing in the benefits of technologically advanced living. This book became a best seller and has been translated into over 20 languages.

In 2000, Negroponte resigned as the director of the Media Lab but continued to act as laboratory chairman until 2006, when he stepped down to focus his attention on the One Laptop per Child Project. Negroponte has contributed to the start-ups of over 30 companies as an angel investor and sits on boards for Motorola and Velti. In 2005, he personally founded the idea of \$100 tablets to aid in the classrooms of children in developing countries. This project has had different names. Originally called the \$100 Laptop, then The Children’s Machine and 2B, it is currently known as OLPC XO. Negroponte designed this laptop for children in developing countries to be compact and durable. It is lightweight and uses an internal SD memory in place of a hard drive. It can also be equipped with different modes to collect power such as a standard plug, human power (a hand crank), and solar power. Externally, it is dirt and moisture resistant and has a sealed, rubber membrane keyboard. The price for these laptops has since increased to \$180.

Michelle Gatewood

See also *Vol. 3, Sec. 1:* IBM 360 Computer; Integrated Circuit; Intel Corporation; Kilby, Jack; Noyce, Robert; *Vol. 3, Sec. 2:* Artificial Intelligence (AI); Computer/Information Technology; Cray, Seymour

Further Reading

Negroponte, Nicholas. 1995. *Being Digital*. New York: Vintage Press.

Nelson, Ted. See Hypertext

Netscape

Netscape or Netscape Navigator was the first widely used Web browser, though it lost its market share in the first so-called Browser War. Netscape was the first company to capitalize on the newly formed World Wide Web.

While working at the Advanced Research Projects Agency in 1963, a psychoacoustics expert named J. C. R. Licklider proposed the idea of a network of computers working together to solve complex problems in real time. His colleagues followed that idea to create ARPANET, the precursor of today’s Internet. Initially, only four computers made up ARPANET, connecting Stanford Research Institute; University of California, Santa Barbara; University of California Los Angeles; and the University of Utah. Incompatibilities between the ARPANET computers, however, led to the development of standardized networking protocols, such as TCP/IP. Other innovations soon followed, such as e-mail, telnet, and file transfer protocol (FTP).

As ARPANET added more computer nodes to its member institutions, it formed in-house or local area networks (LANs). One of these LANs, NSFNET, connected the major supercomputer centers and several universities in 1986. Eventually, NSFNET replaced ARPANET and became the foundation of the modern Internet. As more information flowed across the early Internet, additional protocols and applications became necessary to use it. Participating institutions and users could read electronic bulletin boards, access large databases, communicate with newsgroups, and perform sophisticated queries, but they had to do so with technically complex instructions and a command line interface.

Then, in 1990, Timothy Berners-Lee created Hypertext Markup Language (HTML), which was the basis of his World Wide Web software (later called Nexus) in order to edit and share documents with his colleagues across a computer network. This achievement caught the attention of a student named Marc Andreessen at the University of Illinois at Urbana-Champaign.

At the age of nine, Marc Andreessen had taught himself to write programs in the BASIC language on his TRS-80 computer. By high school, however, he had become bored with computers and only reluctantly chose computer science as his college major. Later, he led a team of programmers at the University of Illinois National Center for Supercomputing Applications (NCSA) to write the Mosaic browser. Mosaic was the most advanced Internet browser in 1993, when NCSA released its source code. Compatible with

several networking protocols and offering a user-friendly, point-and-click interface, Mosaic allowed nontechnical users to share a wider range of content with relative ease.

Upon graduating from college, Andreessen was contacted by James H. Clark, a cofounder and former employee of Silicon Graphics Inc. While Marc envisioned the global impact of the Internet browser, Jim realized its commercial appeal. Together, they formed a new company called Netscape. Andreessen would recruit programmers to make their new product called Netscape Navigator, while Clark put up the seed money for the venture. Some of Clark's former coworkers from SGI also joined the team of engineers at Netscape. Although loosely based on the Mosaic browser, Navigator received two key improvements. The programmers added graphics to the somewhat boring, text-based interface, and they converted it from a Unix-based application to one that worked with Microsoft Windows, an operating system that was running on at least 80 percent of personal computers at the time. Four years later, 50 million people were using the Internet. Netscape remained the technical leader in the Internet browser market through the 1990s, adding more innovations such as independently displayed graphics and text, compatibility with third-party applications, cookies, frames, and JavaScript.

Sixteen months after it was founded, Netscape became a publicly traded company. Netscape's share price was \$28 prior to its initial public offering (IPO). At the opening bell on August 9, 1995, the price rocketed up, reaching as high as \$74.75 per share. At the close of trading that day, Netscape's share price had settled to \$58.25. Lou Montulli had previously joked about his \$600 monthly salary as an engineer for Mosaic. On August 10, 1995, this ragtag group of hungry young programmers had become millionaires overnight. Their incredible success stimulated a firestorm of investing and speculating that seemed like a modern-day gold rush. Fearful of missing the opportunity to ride the Internet wave, venture capitalists poured millions into all kinds of dot-coms. No idea was too outrageous. Some of these tech start-ups, such as Amazon, Priceline, and eBay, for example, succeeded. Netscape's stock reached \$171 per share by the end of 1995.

Fifteen days after Netscape went public, Microsoft released its germinal operating system, Windows 95, without a Web browser, because it had not yet developed one. With help from a Mosaic licensing partner called Spyglass, Microsoft released its first browser, Internet Explorer, with the Windows 95 Plus! Pack. During a legal dispute with Spyglass, Microsoft revealed that it was bundling Internet Explorer with the Windows operating system. Put another way, Microsoft claimed that Internet Explorer was not a separate product from Windows—rather, it was an integrated feature of Windows. This critical point became the basis of Microsoft's defense against a lawsuit brought by the U.S. Department of Justice in 2000. In his finding of fact, Justice Thomas Penfield Jackson declared that Microsoft had abused its monopolistic power by diminishing the presence of competing products on the Windows desktop through negotiations with computer manufacturers by attempting to dissuade Netscape from developing Navigator as a platform and by excluding Navigator from important distribution channels.

Despite these findings, Microsoft continued to dominate the operating system market with Windows and gradually pushed Netscape out of the public eye while increasing the functionality of Internet Explorer. Netscape released its source code and created the Mozilla Organization to coordinate future projects. In 1999, AOL acquired the remaining Netscape stock for about \$10 billion. In the mid-1990s, Netscape's usage share was 90 percent. By 2006, it had dropped to less than 1 percent. Microsoft had won the Browser Wars.

Peg A. Lamphier

See also Hypertext; *Vol. 3, Sec. 2*: Internet; Microsoft; Perlman, Radia

Further Reading

- Heilemann, John. 2000. "The Truth, The Whole Truth, and Nothing But The Truth." *Wired* 8, no. 11: 260–311.
- Lewis, Michael J. 2001. *The New New Thing: A Silicon Valley Story*. New York: Penguin Books.
- Reid, Robert H. 1997. *Architects of the Web: 1000 Days That Built the Future of Business*. New York: John Wiley and Sons.

Nye, Bill (1955–)

Known worldwide as “Bill Nye the Science Guy,” from his public television show of the same name, Bill Nye is the most famous science communicator in the United States and is known for his wacky performance style and iconic bow ties.

Born William Sanford Nye in 1955, Nye graduated from Cornell University with a degree in mechanical engineering in 1977. His first job was for Boeing, an aviation company in Seattle, Washington. In 1986, Nye quit his job so that he could devote more time to his comedy career. In 1993, Nye developed his now famous *Bill Nye the Science Guy* for a public television station in Seattle, pitching the show as a mash-up



Loved by generations of young Americans, Bill Nye is one of the nation's great public scientists. His PBS show *Bill Nye the Science Guy* and Netflix show *Bill Nye Saves the World*, along with his quirky personality and colorful bowties, have made him famous around the world. (Carrielson1/Dreamstime.com)

of *Pee-wee's Playhouse* and Mr. Wizard. The show quickly gained an audience of both children and adults and was picked up by public television stations across the country. The show's immense popularity disguised its effective science teaching with humor and fast-paced action. The show ran for 100 episodes.

In the 21st century, Nye has taken on more controversial science topics, including challenging climate change and evolution deniers and warning of the dangers of genetically modified foods. In 2017, Nye returned to video, if not television, with the Netflix show *Bill Nye Saves the World*. He also took a leadership role in the 2017 March for Science.

Emma E. L. Burke

See also March for Science; Tyson, Neil deGrasse

Further Reading

Nye, Bill. 2014. *Undeniable: Evolution and the Science of Creation*. New York: St. Martin's Press.

One Laptop per Child

One Laptop per Child (OLPC) is a nonprofit organization whose mission is to transform education and empower the children of developing countries by creating low-cost computers for underprivileged schools. OLPC achieved this goal by creating devices as well as software and content for them. OLPC's objective is to transform the learning process by providing a means for exploration, learning, and self-expression to the children of developing nations who have little or no access to education. OLPC believes that children are eager to learn, and those given laptops will have more ability to access information. It is hoped that they will then more fully contribute what they learn to the community.

American architect Nicholas Negroponte is the founder and chairman of the Massachusetts Institute of Technology's Media Lab. Negroponte founded One Laptop per Child while at the Media Lab. OLPC wanted to create low-cost machines, since current computers were too expensive. There were issues with software specs and hardware, but after six years, OLPC completed a laptop. It cost \$200, though it was originally supposed to cost \$100.

OLPC has been praised for providing low-cost machines to children in developing countries. One Laptop per Child reported that “more than 3 million laptops” had been shipped as of 2015. Still, the non-profit faces criticism from representatives of developing countries. Clean water and a lack of schools are prominent issues in these countries, so money spent on technology is not always viewed as a priority. Several African representatives at the World Summit on the Information Society held by the United Nations in 2005 voiced concerns over the motives of the OLPC project. They were suspicious of the “U.S. mindset” of the laptop’s software and programs, and they felt the laptop wasn’t applicable to “African problems.” Uruguay was the first country to purchase a full order of 100,000 laptops in 2007. The laptops have so far cost the state \$260 per child, including equipment repairs, Internet connections, and training for teachers. An information portal for pupils and teachers will be included in the annual maintenance cost of \$21 per child.

Rachel Alzaga

See also e-Book and e-Reader; iPod; Wireless Communication; *Vol. 3, Sec. 2: Computer/Information Technology*; Personal Computer (PC)

Further Reading

Hacker, Robert H. 2014. *Scaling Social Entrepreneurship: Lessons Learned from One Laptop per Child*. Charleston, SC: CreateSpace Independent Publishing Platform.

Kane, Charles, Walter Bender, Jody Cornish, Neal Donahue, and Mark Rennella. 2012. *It’s Not (Just) About the Laptop: One Laptop per Child and the Movement to Improve Education Across the Globe*. London: Palgrave Macmillan.

Onion Router. See TOR (The Onion Router)

PayPal

PayPal is the world’s largest online payment system, supported with a host of online commercial ventures as the payment processing option of choice.

Peter Thiel, Max Levchin, Ken Howery, and Luke Nosek founded Confinity in 1998. The company specialized in security software, and the founders discovered they needed an in-house money transfer system. John Malloy at BlueRun Ventures funded the company add-on in 1999. A year later, Elon Musk merged his online banking company with Confinity. The company was renamed PayPal in 2001, and Peter Thiel replaced Musk as the company’s chief executive officer. PayPal became a publicly traded company in 2002, and shortly afterward, eBay acquired the company as a subsidiary. Thus began PayPal’s domination of the online payment market.

In the early 2000s, other companies, including Pay Direct, c2it, BidPay, and Google Checkout also offered online payment services. Each company found itself in competition with PayPal, and each company eventually failed. After eight years of business, Paypal had over 100 million user accounts, using 25 different currencies in 190 markets worldwide. Paypal continues to enjoy market dominance, driven by its ease of use for consumers.

Emma E. L. Burke

See also Wireless Communication; YouTube

Further Reading

Jackson, Eric. 2012. *The PayPal Wars: Battles with eBay, the Media, the Mafia and the Rest of Planet Earth*. New York: WND Books.

PGP Encryption

PGP, or *Pretty Good Privacy*, is a well-known program used to encrypt and decrypt e-mail over the Internet. It is used to authenticate messages with digital signatures and encrypt stored files. It is also the most widely used encryption software available and considered a critical element to online privacy.

The cryptography software PGP was created in 1991 by Phil Zimmermann, a programmer and special director of Computer Professionals for Social Responsibility (CPSR), to promote awareness of privacy issues in a digital age. Even though Zimmermann created PGP, it drew on a long history of cryptographic

discoveries. Cryptography is the writing of messages in secret code. Encryption makes secrecy possible, and PGP was one of the strongest encryption tools available to the public. PGP was originally designed as a combination of RSA (a public key cryptographic algorithm) encryption and a symmetric key cipher known as Bass-O-Matic (a conventional or symmetric) key algorithm, which was later replaced by IDEA because it enabled a more secure encryption technology.

The encryption technology works by using two keys that are required to encrypt and decrypt a secure message; one is public and the other private. For example, if someone wants to send a friend a secure communication, he or she downloads the friend's public key and uses it to send the coded message. The friend's public key has a corresponding private key (which only the friend should have), and this is used to decode the message. When encrypting a message, PGP uses a faster encryption algorithm, which then uses the public key to encrypt the shorter key that is used to encrypt the entire message.

PGP can be used to validate digital certificates and encrypt or decrypt texts, files, e-mail, directories, and so forth. Symantec is one company that offers PGP-based products for encrypting files shared across a network with Symantec File Share Encryption; and for full disk encryption on desktops, mobile devices, and removable storage, it offers Symantec Endpoint Encryption. These Symantec products allow users to decrypt and re-encrypt data via a single sign-on when PGP technology is used for files and drives instead of messages. PGP encrypted e-mail nowadays can be exchanged with other users outside of the United States if both ends have the correct versions of PGP. The original PGP technology went out of date and was bought by Symantec, so now it has been replaced by free software called *GNU Privacy Guard* (GPG or GnuPG).

Kathleen Phan

See also Vol. 3, Sec. 2: Personal Computer (PC)

Further Reading

Shneier, Bruce. 1996. *Applied Cryptography: Protocols, Algorithms, and Source Code in C*. 2nd ed. New York: Wiley.

Zimmermann, Philip R. 1995. *PGP: Source Code and Internals*. Cambridge, MA: The MIT Press.

Zimmermann, Philip R. 1996. *The Official PGP User's Guide*. Cambridge, MA: The MIT Press.

Plan B. See RU-486/Plan B

Quantum Science

Quantum science is the field of science focused on the smallest components of atoms; it studies how they react to stimuli, deeply involving the disciplines of both engineering and technology. Max Planck, a physicist and creator of the Planck length (the shortest length that can exist) started the quantum revolution in 1900 when he published a paper on black body radiation, a theory that describes how hot objects emit light. Albert Einstein was initially against the explanations of certain quantum phenomena because they did not follow his theory of general relativity, but he eventually began research in the field.

In the 18th century, Isaac Newton first speculated that light traveled in packets of energy that he called "corpuscles," which modern science has renamed "photons." The scientific community at first dismissed Newton's speculation in favor of the widely accepted theory of light as a wave. In 1801, physicist Thomas Young performed an experiment in which light was shined through a barrier with two parallel slits that let the light pass through onto another wall, where the resulting wave pattern could be studied. The interference pattern matched what was expected if light behaved as a wave.

In 1905, Einstein marked the end of what is now called the era of classical physics and the beginning of the quantum era by publishing his findings on the photovoltaic effect, the basic process in which a solar cell converts sunlight into electricity. The photovoltaic effect is what CRT televisions and monitors used to use to display images, but in today's digital world, this effect is concentrated in solar panels. Einstein's finding described light as a particle, as photons hit the electrons out of their atoms. These results indicate a wave-particle

duality, showing that an entity such as light has the properties of both a wave and a particle. This phenomenon is not just a property of light but can be seen in other fundamental particles such as electrons.

In 1920, Niels Bohr created an atomic model of electron energy levels in which the electrons orbit in shells, each shell having its own energy state. As an electron becomes energized, it moves from one energy state to the next. When an electron moves to a lower state, energy is released in the form of light. The wavelength of this light depends on the distance between the energy levels the electron moves through. This theory powers spectroscopy, which has been used since the 20th century to determine the elemental makeup of distant stars by measuring the wavelengths of light emitted from them. For this work, Bohr received the Nobel Prize.

In 1932, Werner Heisenberg was awarded the Nobel Prize for his publishing on the standard proton, neutron, electron model of the atom. His contribution to the quantum world is known as the “Heisenberg uncertainty principle.” This principle states that a particle’s position and momentum cannot both be known. In other words, if the position of a particle is known, its momentum remains a mystery; and so, the opposite is also true. Similarly, in 1933, Erwin Schrödinger received a Nobel Prize for his equations describing how physical states change over time, taking into consideration quantum effects. His “Schrödinger’s cat” thought experiment illustrates the behavior of quantum states, in which all possibilities exist until observed or measured.

In the 20th century, laser light was achieved by implementing a quantum property of the atom, making lasers useful in the medical field for surgical procedures, the construction industry for leveling, the military for tracking, and in the household to read data off CDs, DVDs, and Blu-ray discs. In modern times, computer processors can contain over a billion transistors, which are like gates that allow current to pass through when activated. Bohr discovered the principle behind transistors when he described electrons falling into lower-level orbital shells.

Today, we know that the atom does not completely match the Bohr model, where the electron orbits the nucleus like a planet around a star. Instead, the atom

exists in probability zones, where at any given time, the electron can be found within them. While normal computers operate on a two-bit system, where at any time, the bits can be either a one or a zero, but not both, quantum computers use qubits (quantum bits), which can hold both states at the same time—the superposition of the qubit. With this kind of system, all possible combinations of qubits can exist at once.

Rosanne Welch

See also *Vol. 2, Sec. 2:* Einstein, Albert; *Vol. 2, Sec. 3:* Television; *Vol. 3, Sec. 2:* CD and DVD

Further Reading

Forshaw, Jeff, and Brian Cox. 2011. *The Quantum Universe*. Da Capo Press.

Susskind, Leonard, and Art Friedman. 2014. *Quantum Mechanics*. Basic Books.

Walker, Michael S. 2017. *Quantum Fuzz*. Prometheus Books.

RFID Labels

In January 2005, Walmart, the nation’s largest retailer, announced to its top 100 suppliers that radio-frequency identification (RFID) labels would be required on all pallet shipments. Many consider this event the beginning of a revolution in inventory management and package tracking. RFID uses a microchip label to emit radio waves to transfer data to an electronic reader. RFID product tags can accurately update inventory routinely without human labor and in seconds, reducing the time to take inventory, and they help manage the entire ordering and delivery needs of the supply chain. They also make delivery tracking throughout the supply chain easy. In the store, RFIDs offer quick electronic checkout and huge savings are possible by avoiding out-of-stock situations. Commercial experiments are now underway to tie RFID tags with smartphones for credit card purchases and other applications, such as electronic toll collection. While the benefits are huge, problems with the initial costs and privacy and security concerns remain.

The technology of RFID is a confluence of several streams of development. Its earliest roots go back to



The radio frequency identification (RFID) tag can be used as an alternative to bar codes to tag wildlife, identify medical patients, and more. (Vetkit/Dreamstime.com)

the development of electrical transponders to identify planes at the end of World War II. The more recent history is one of miniaturization. The earliest patents occurred in the 1980s; the tags then consisted of a microchip with an integrated circuit for storing, processing, and sending data. Most have a small, built-in battery that can be activated in the presence of a reader or can actively broadcast. Some low-cost ones are passive (having no battery) and are read by a mobile sensor/reader, since broadcasting is presently limited to a few yards. The active battery-powered tags are very expensive (over \$50), and therefore they are applied to larger and more expensive items.

Walmart is one of the few retailers big enough to help push implementation of RFID down the supply chain. However, in 2007, the U.S. Department of Defense (DoD) also requested RFID labels on many of its purchases. The DoD has since mandated it on

most pallet shipments according to MIL STD 129. Walmart's initial 2007 plan was to use smart labels on all pallets going to its stores and Sam's Club. As might be expected, suppliers were not happy and dragged their feet. Sam's Club imposed a threatening \$12-per-pallet penalty, which it later reduced to 12 cents a pallet. Walmart issued a full-implementation target for pallets by 2010, though the target was not reached. Other retailers and wholesalers have joined in on pallet shipments, such as Procter & Gamble. In 2010, Walmart took a larger step in implementing RFID tags on clothing. At the same time, J. C. Penney was experimenting with RFID.

RFID offers potential huge savings in inventory control, reduction of lost sales due to better stocking, and reduction in theft. Walmart studies suggest that out-of-stock situations could be reduced as much as 30 percent, translating into more sales. Inventory control

software has made big advances since the 1990s with material requirement planning (MRP). MRP systems can be a real advantage in inventory management, but they require an accurate physical count to function properly. RFID offers the accuracy to improve the function of MRP and inventory control software. The cost of hand scanning of inventory is eliminated. The ability of RFID technology to instantly provide an updated, accurate picture of inventory on hand and shipments in transit mean large savings. In addition, the impact on theft would be just as big. One problem, however, is concern over privacy and tracking beyond the store. Another is that in-store scanners could access digital codes embedded in credit cards or special driver's licenses.

Applications are expanding beyond retailing as well. Assets can be tagged and readily inventoried at year end. Banks such as Wells Fargo and Bank of America are using RFID tags on information technology assets. One of the earliest uses of RFID included tagging of animals after the outbreak of mad cow disease. Some casinos are using embedded RFID tags on high-value chips to detect counterfeit chips and invalidate stolen chips. One area of research continues to be automatic checkout systems and payment. Today, Intermec Technologies and Symbol Technologies (Motorola) are the major manufacturers. Tag prices are coming down, which will encourage more implementation. Interestingly, the path forward can be found in the implementation of bar code technology.

Quentin R. Skrabec

See also Smartphone and 3G Network

Further Reading

- Bustillo, Miguel. 2010. "Wal-Mart Radio Tags to Track Clothing." *Wall Street Journal*, July 23.
 Lahiri, Sandip. 2011. *RFID Sourcebook*. Armonk: NY: IBM Press.

RU-486/Plan B

RU-486 is the most common type of "morning-after pill" used as an emergency contraceptive by women who have had unprotected sex. It can also be used in the first three months of pregnancy to effect a medical

abortion. It is safe and effective at protecting women against unwanted pregnancies. The approval of RU-486 in September 2000 by the Food and Drug Administration in the United States gave women new levels of control over their bodies. Antiabortion advocates argue against RU-486 and medications like it, saying that they will make abortion more common. National statistics do not bear out this claim.

RU-486 (under the brand name Mifeprex) is a complex chemical that effectively blocks P receptors in the placenta so that fertilized eggs cannot implant themselves, resulting in the termination of pregnancy. In addition, it has been used in the treatment of leiomyomata, endometriosis, advanced breast cancer, and meningioma. It may be used as an estrogen-free contraceptive.

It has been widely, effectively, and safely used in France, Sweden, and Great Britain since the 1980s. Roussel Uclaf, the company that held the RU-486 patent, did not seek approval from the USFDA. In 1995, the company ceded American rights to the drug to the Population Council, which sought FDA approval. Clinical trials in the United States began in 1994 and 1995, and the drug was approved by the FDA in September 2000. RU-486 is used in the United States both as an emergency "morning-after" pill and as a first-trimester (the first three months of pregnancy) medical abortifacient. RU-486 and similar medications can also be delivered by an intrauterine device (IUD) for long-term (up to 12 years) birth control.

In 1999, the FDA approved Teva Pharmaceutical Industries to market an emergency contraceptive set of drugs commonly called "Plan B" to prevent pregnancy. The first pill is taken within 72 hours of unprotected sex and the second 12 hours later. In 2001, the Center for Reproductive Rights and other groups petitioned the FDA to make the drug available without a prescription. Antiabortion advocates argued that the pills would be too accessible to minors, and the FDA ignored the petition, probably to avoid a political storm. In 2006, the FDA first rejected the petition and then later in the year approved it. Plan B could now be sold without a prescription in drugstores. Three years later, Teva Pharmaceutical Industries came out with a one-pill version, or Plan B One-Step.

Planned Parenthood reports that in the wake of *Roe v. Wade* (1973), which legalized abortion in the

United States, 3 of 10 American women will have an abortion before they are 45 years old. More than 75 percent of women who have an abortion say they could not afford the child. RU-486 is also used as a safe alternative to surgical or in-clinic (vacuum aspiration or dilation and evacuation) abortions. Medical abortions are 98 percent effective, though there are rare allergic reactions to the drugs. Medical abortions are less intrusive and more effective than surgical abortions, offering women who do not want to continue a pregnancy a superior medical treatment.

Antiabortion advocates object to all types of abortion and thus object to RU-486. Some antiabortion activists object to abortion when a woman's pregnancy is the result of rape. A small number of conservative antiabortion activists believe that a pregnancy cannot result from rape. Medical science disputes this claim, pointing out that no study has ever found a connection between a woman's desire or reluctance to have a baby and the fertilization of an egg.

While both contraception and abortion remain politically fraught topics, almost 90 percent of Americans believe that contraception is moral and within a woman's rights, and 53 percent of Americans agree with *Roe v. Wade*. Pro-woman advocates point out that women can never have true equality if they cannot control their own bodies and their fertility.

James A. Wren and Peg A. Lamphier

See also Vol. 3, Sec. 1: Birth Control Pill

Further Reading

Zeigler, Mary. 2015. *After Roe: The Lost History of the Abortion Debate*. Cambridge, MA: Harvard University Press.

Science Friday

Science Friday is a popular podcast heard weekly by millions of listeners on Public Radio International and on the Internet. It covers topics such as news, nature, science, and technology in an entertaining and informative way. The podcast was created when the National Science Foundation agreed to fund a weekly talk show about science. After the cancellation of National Public

Radio's talk show *Talk of the Nation*, *Science Friday* was spun off as its own radio show. *Science Friday*'s recording takes place in New York, New York. The podcast has a total of 31 staff members. The director is Charles Bergquist, and the executive director is Danielle Dana. The host and executive producer of the talk show is Ira Flatow. Flatow is a science correspondent and a TV journalist. Each staff member is engaged on social media, mainly on Twitter, to give insights on science-related topics and communicate with their fans as well.

Science Friday began in 1991 and is still on the air as of 2018. With 374 public radio stations and 1.3 million listeners, *Science Friday* is the most influential science-based radio show in the nation. Approximately 23 million downloads per year made it one of the most popular iTunes downloads in 2017.

Not only does the program provide information on topics such as science, nature, and technology, but so does its Web site, www.sciencefriday.com. The site offers entertaining educational materials and original videos for the fans to learn new information on whatever topics are being covered. Also, the talk show has interesting segments where authors and scientists discuss their newsworthy achievements.

With millions of audience members tuning in to *Science Friday*, the podcast has achieved awards and recognition for high-quality journalism.

Lusine Davtyan

See also Hawking, Stephen; Tyson, Neil deGrasse; Vol. 2, Sec. 2: Radio

Further Reading

"Undiscovered Presents: The Magic Machine." <https://www.sciencefriday.com/>, accessed September 26, 2018.

SETI (Search for Extraterrestrial Intelligence)

The Search for Extraterrestrial Intelligence (SETI) is an organized effort to detect alien communications. SETI researchers have concentrated their efforts in specific areas of the sky. Although SETI was begun by one

man, over time, technological innovations have helped make it a group effort. Advancements have also helped researchers scan in better and new ways. Although SETI researchers have uncovered a few unexplained signals over the years, they have yet to conclusively confirm the existence of alien intelligence.

In 1959, physicists Giuseppe Cocconi (1914–2008) and Philip Morrison (1915–2005) published a paper in which they stated that radio signals within a range of 1 to 10 gigahertz would be best for interstellar communications. That same year, astrophysicist Frank Drake (1930–) established the first SETI program. Drake garnered support from the scientific community for the search with his Drake equation, which is a way of estimating the number of communicative extraterrestrial civilizations that may exist in a galaxy. By the early 1960s, another SETI program was established at The Ohio State University (OSU). OSU professors and students used “Big Ear,” a 360-foot-wide, 500-foot-long, and 70-foot-high radio telescope to listen to distant stars.

In the late 1960s, the National Aeronautics and Space Administration (NASA) began supporting search initiatives. NASA scientists devised several SETI-related programs, including the Microwave Observing Project, Project Orion, and the High-Resolution Microwave Survey. Although NASA functioned in a supportive capacity from the 1960s to the 1980s, its direct involvement in SETI was minimal. In contrast, in 1992, NASA began an intensive SETI program. It lasted only one year, because the U.S. Congress cut its funding.

Since that time, SETI initiatives have relied heavily on private funding and volunteer participants. SETI has evolved into several different groups with slightly different approaches to the same objective. The development of new technologies has nurtured a team approach to the search. For example, since 2004, more than 5 million volunteers from around the world (from over 200 countries) have collectively donated millions of years of computer data analysis time. Since 2006, the University of California, Berkeley sponsors SETI@home, which is a distributed computing project. Data collected at the Arecibo Radio Observatory (ARO) is sent to Berkeley, where it is then divided into units that are sent to personal computers around the

world. Each volunteer then spends many hours examining the individual unit, looking for possible alien radio signals. If a volunteer believes he or she has found a candidate signal, it is sent back to Berkeley for further analysis.

Other Berkeley SETI initiatives include the Search of Extraterrestrial Radio Emissions from Nearby Developed Intelligent Populations (SERENDIP), Southern SERENDIP, and Optical SETI. In addition to ARO, Berkeley also has access to the Allen Telescope Array (ATA), an array of antennas equivalent to a single enormous dish. Project Phoenix uses a receiver that is much more sensitive than other SETI radio telescopes. The state-of-the-art receiver is capable of amassing radio energy for longer periods, and the clearer radio wave picture allows scientists to analyze data faster and more precisely. Other innovations have allowed some projects to search within more regions of the electromagnetic spectrum.

The observable universe is vast and expanding. By 2017, astronomers had observed evidence of the existence of more than 100 billion galaxies in the universe. NASA scientists theorize that that number will increase significantly as Earth’s telescope technology improves. In addition, scientists have speculated about the existence of many more galaxies beyond the earth’s light horizon (the point at which light from distant stars has reached the earth), which will remain unobservable by any means as the universe continues to expand. Our own Milky Way galaxy measures approximately 100,000 light years in diameter, and it contains more than 100 billion stars. Many of those stars have planets that orbit them.

Present-day technology precludes humans from physically traveling to distant galaxies to explore them. In fact, even our own galaxy’s vastness renders unmanned probes impractical for its complete exploration. Radio waves, which have been in use for a little over a century on earth, travel at the speed of light. This means that to date, Earth’s earliest radio signals have only reached about 100 light years into our galaxy. However, even though Earth’s radio signals presently have a comparatively limited range, the radio signals of other, much older planets may theoretically reach Earth. This expectation (or hope) serves as the incentive for SETI participants.

Due to the vastness of the search area, SETI participants have narrowed their searches based on certain assumptions (that may or may not be accurate). The first assumption is that a star similar to the earth's sun is necessary for any kind of life to evolve on an alien planet. The second assumption is that the presence of an Earth-like sun and water on a planet is necessary for the development of intelligent life. Using these two assumptions as their criteria, SETI participants have estimated that 10 percent of the stars (about 1,000) in our galaxy are similar to our sun. Consequently, SETI participants have concentrated most of their attention in these areas.

The most famous unexplained signal ever found by SETI occurred on August 15, 1977, when astronomer Jerry Ehman wrote the word, "WOW!" on the margin of a computer printout he was examining. Since that time, countless efforts have been made to recapture the same signal. For example, SETI used the ATA to collect 100 hours of new data from the same direction of the WOW! signal, but nothing was found. The null result did not deter SETI researchers. In fact, SETI observations of the same area of space are still in progress. Many SETI participants still regard the WOW! signal with awe. On August 15, 2017 (40 years after the event), the official SETI Institute Web page posted, "Happy Birthday WOW!"

In 2016, Antonio Paris, a professor of astronomy at St. Petersburg College in Florida, reported that a comet was likely responsible for the mysterious signal. Paris stated that the signal was a match for a signal emitted by a more recent passing comet. Although it was impossible to determine if the comet he had observed was the same one that might have caused the irregular reading 40 years before, he was certain that the WOW! signal was not the product of alien intelligence. Paris confessed to be disappointed by his finding.

After searching for more than half a century, SETI has yet to find conclusive proof of intelligent extraterrestrial life. Some scientists have contemplated a few possible reasons for this phenomenon. Perhaps the assumptions that SETI scientists have made in determining where to search have been incorrect. Perhaps alien civilizations do not exist, and Earth is a solitary anomaly. Or, Earth may be the first intelligent civilization to

emerge among many more that may come later. In these two previously described scenarios, there would be no messages for Earth to find. According to the Drake equation, not all intelligent life forms may have discovered radio waves, or they may not be willing or able to communicate with Earth. A doomsday-type scenario states that all intelligent life may annihilate itself after reaching a certain level of technological advancement, and therefore, radio signals that may one day reach Earth may be from a civilization that no longer exists. Finally, even if a planet contains a thriving civilization, it may be too far away from Earth for its radio waves to reach us.

In spite of these possibilities or any other obstacles, the SETI community seems as determined as ever to keep searching. In recent years, only about 50 percent of the visible sky had been scanned more than once, and 10 percent of the visible sky had still not been scanned at all. The development of NASA's Kepler space telescope allowed astronomers a much better view of the universe, because its lenses were not obstructed by Earth's atmosphere. Kepler has aided astronomers in the discovery of new planets that orbit suns. These discoveries have given SETI a greater range of target search areas. In addition, many radio frequencies are still unexplored. In truth, even a thousand years of searching would be a drop in the bucket given the vastness of the search area. It remains to be seen how the development of new technologies will both reshape the SETI organization and enable a better view of the scannable sky.

Rolando Avila

See also Drake Equation; International Space Station; *Vol. 2, Sec. 2: Radio*; *Vol. 3, Sec. 1: Satellites and Space Probes*; Space Science and Technology; Voyager Spacecraft; *Vol. 3, Sec. 2: Space Shuttle Program*

Further Reading

- Bova, Ben. 2004. *Faint Echoes, Distant Stars: The Science and Politics of Finding Life Beyond Earth*. New York: William Morrow.
- McConnell, Brian S. 2001. *Beyond Contact: A Guide to SETI and Communicating with Alien Civilizations*. n.p.: O'Reilly and Associates.

Sagan, Carl. 1997. *Project Haystack: The Search for Life in the Galaxy*. Mountain View, CA: SETI Institute, Teacher Ideas Press.

SETI@home. <https://setiathome.berkeley.edu>, accessed August 31, 2018.

SETI Institute. <https://www.seti.org>, accessed August 31, 2018.

Smartphone and 3G Network

The 3G network, as the third generation in mobile telecommunications is known, has a complex history because some of the engineering advances that define a third generation are subjective. This third generation of telecommunications was driven more by standards and network protocol than by technology and meets the international specifications, called International Mobile Telecommunications-2000 (IMT-2000), of the International Telecommunications Union. This wireless communications network supports a wide range of devices such as smartphones, mobile laptops, videophones, and mobile television. Japan was the first to launch a true 3G network in 2001. The standard allows for more broadband efficiency than 2G and speeds of 6 to 15 megabits per second to support smart devices, although technically, the standard requires peak data rates of only 380 kilobits. The 3G networks use different radio frequencies than 2G does. 2003 stands out as the year of American 3G networks, or mobile broadband, when Verizon and AT&T (Cingular at the time) introduced their 3G networks. The arrival of 3G expanded the use of cell phone devices into video e-mail, mobile television, movie watching, Internet surfing, and video conferencing.

In late 2003, Cingular had its 3G wireless network ready, but it needed a breakthrough device to push network use and profits. The very first 3G phones to hit the market in 2003 were heavy and large; they were very unpopular. Wireless companies looked for a manufacturer to popularize 3G, but they wanted complete control. Their voice phone business was peaking, and profit margins were declining. The 3G network offered the potential for high-profit-margin data users to download music, books, and videos and to surf the

Internet. Wireless phone carriers such as Cingular and Verizon had gotten used to defining the devices to be used. Steve Jobs at Apple Computer was looking at a much different relationship in the development of a multiuse cell phone of the future. Apple had already successfully moved into the MP3 music market with its iPod. Jobs envisioned a single device to function as an Internet, music, and phone device. It was the perfect utilization of the 3G technology.

In 2005, Jobs launched a team of 200 engineers on the iPod development project while he started secret negotiations with Cingular. Jobs realized that competitors were watching, and he wanted to assure secrecy. This was a major breakthrough, and he well remembered how Microsoft had pirated his operating system. He spread out his team members and separated his hardware and software teams. Visits to Cingular were kept secret, and members signed in as employees of Infineon. He also had developed an advanced touch screen for his failed PC tablet that competitors still had not duplicated, and he planned to use it in his new iPhone. The whole time, Jobs publicly denied that any work was being done on a cell phone. But Apple was working with Motorola and Cingular on a music phone to be released in 2005 known as “ROKR.” The ROKR, with an Apple operating system and supported by its iTunes library, did come out in late 2005. The 2007 release of the iPhone made the ROKR obsolete. The iPhone was able to hold 1,500 songs versus 100 for the ROKR. The ROKR also had a bulky, walkie-talkie-like appearance, which added to its unpopularity. The June 28, 2007, release of the iPhone was an amazing testament to Apple’s market following. Estimates of sales for the first weekend were as high as 700,000.

The development of the iPhone was the perfect combination of Apple’s search for a high-profit device and the carriers’ search for a breakthrough application. The competition between carriers such as Verizon and AT&T (which purchased Cingular at its peak in 2006) allowed Apple to take leadership in the manufacturing and design of the new generation of cell phones. Jobs found himself in the driver’s seat with his proposed iPhone. Jobs wanted to break the earlier cell phone model where cell phone manufacturers profited on the

sale of the devices rolled into a time-specified contract. Jobs wanted higher profit margins and to profit from the usage as well. Negotiating with AT&T, which at the time was losing market share to Verizon, Jobs had huge leverage. The iPhone could offer a huge flood of new customers. Jobs even pushed AT&T (Cingular) to assure video e-mail over the network. Jobs also demanded complete commercial and manufacturing control over the iPhone, and he got what he wanted. Apple would make a profit of about \$150 on the initial selling price of \$599 and \$10 a month from every AT&T bill on a two-year contract. Even after the initial price was reduced to \$399, Apple still made \$80 per phone.

The iPhone business model caused manufacturers to design for customer approval rather than for carrier approval as had been the case in the cell phone business model up until then. Prior to the iPhone, carriers determined the prices and features of the phones being offered. The results lived up to every hope and dream of Apple. It sold over 3 million phones in the six final months of 2007, returning more than the estimated development cost of \$150 million. Google's Android phone came into the market because of the exclusive initial deal with AT&T. The iPhone created a whole new industry of phone applications to develop all of the iPhone's capabilities. Carriers that lost their control over wireless devices were even looking at wireless banking to expand their services along with the iPhone's capability.

The expansion of 3G networks rejuvenated the stalled technology of electronic books with devices such as Amazon's Kindle. These 3G electronic books redefined the selling of books and accelerated the decline of brick-and-mortar stores. 3G proved to be a major commercial advance, more so than the first two generations of wireless communications.

Quentin R. Skrabec

See also Amazon.com; *Vol. 3, Sec. 2: Apple*

Further Reading

Elliot, Jay, and William L. Simon. 2011. *The Steve Jobs Way: iLeadership for a New Generation*. New York: Vanguard.

Vogelstein, Fred. 2008. "The Untold Story: How the iPhone Blew Up the Wireless Industry." *Wired* (January 9): 27–28.

Tarter, Jill (1944–)

Jill Tarter is an astronomer and cofounder of the Search for Extraterrestrial Intelligence (SETI) Institute in California. Tarter is currently the holder of the Bernard M. Oliver Chair for SETI. She has dedicated her career to the search for extraterrestrial life outside of our solar system.

Tarter was born on January 16, 1944. As a child, Tarter was always more into male-dominated activities than other girls her age. Her father taught her about constellations and the sky at night. Tarter always wondered if humans were the only ones in this universe, which is why, at eight years old, she decided to be an engineer.

Tarter is a descendant of Ezra Cornell, the founder of Cornell University. As an adolescent, Tarter wanted to attend Cornell. Unfortunately, her family couldn't afford to send her to college. The only way she could attend was to win scholarships. She applied for a scholarship specifically for descendants of Cornell but was not eligible because it was only given to males. Tarter was accepted into Cornell through a different scholarship, but she was the only woman in a class of 300 engineering students. Tarter received her bachelor's degree in engineering physics and later received a master's and PhD in astronomy from the University of California, Berkeley.

In graduate school, Tarter was involved in projects that were specially designed to find radio frequencies that might come from alien life forms. This project was part of SETI, which was very small at the time. Tarter enjoyed the projects and studies so much, she decided to dedicate her life to SETI and become a guiding force behind it. Tarter was a part of a project called Project Phoenix, where the SETI Institute performed a decade-long experiment observing 750 star systems. SETI sent radio signals out from Puerto Rico, West Virginia, and Australia. No sign of extraterrestrial life was found, but this was Tarter's biggest project ever in trying to find evidence of life outside of what we know on Earth. Tarter was one of the first women to pioneer our search for extraterrestrial life.

Tarter's work and dedication to her career have brought her many awards, including the Lifetime Achievement Award from Women in AeroSpace. She



Jill Tarter, at the SXSW Music, Film and Interactive Festival in 2013. Tarter is a vigorous proponent of science education. (Rita Quinn/Getty Images for SXSW)

was named one of *TIME* magazine's 25 Most Influential People in Space. She received two Public Service Medals from NASA, the TED Prize in 2009, and Silicon Valley's Women of Influence Award in 2010. Asteroid 74282 Tarter was named after her. She was also listed in *TIME* magazine's 100 Most Influential People in the World in 2004. In 2012, Tarter stepped down from SETI after 35 years. Gerry Harp, who is a physicist at the SETI Institute, became its next research director. Although Tarter is now retired, she dedicates her time to hosting fundraisers for SETI's current work.

Pamela Solis

See also *Vol. 3, Sec. 1*: National Aeronautics and Space Administration (NASA); Space Science and Technology

Further Reading

Impey, Chris. 2011. *Talking about Life: Conversations on Astrobiology*. Cambridge: Cambridge University Press.

Shostak, G. Seth. 1988. *Sharing the Universe: Perspectives on Extraterrestrial Life*. Berkeley, CA: Berkeley Hills Books.

Thompson, Ken (1943–)

Ken Thompson is the computer scientist who created the Unix operating system and the C language with Dennis Ritchie. In 1983, he shared the A. M. Turing Award given by the Association for Computing Machinery for contributions of lasting and major technical importance with Dennis Ritchie for inventing the Unix operating system at Bell Laboratories.

One of the most important advantages of Unix is its clean and simple interface. Also, Unix was shared freely with universities early on, so students could adopt it quickly. Unix is very important in the history of computer science because it is the backbone of the computerized technical infrastructure of the modern world.

Thompson was born in 1943 in New Orleans, Louisiana. He was always interested in studying logic and liked to solve arithmetic problems in binary. He received his bachelor's and master's degrees in electrical engineering from the University of California, Berkeley (UCB). He was then hired by Bell Labs, where he participated in a project called the Multiplexed Information and Computing Service (MULTICS). Eventually, the project grew too complex to control, and it was vulnerable to criminal hackers. For this reason, Bell Labs stopped the project.

Thompson worked on Unix, which began as a scaled-down version of the MULTICS. In 1969 he created a game called *Space Travel* that helped pilots practice flying in space just as humans first went to the moon. It was not only the first computer game but the first application to run on the Unix operating system. In the process, he gained a better understanding for the development of Unix. One of the most important factors for his success was his PDP-7 computer, which was the first to run his operating system. It had an 18-bit word length and only four kilobytes of memory. Because it had such a small memory, Thompson needed to keep his operating system small. In other words, his philosophy of simplicity arose because the PDP-7 was not a powerful-enough computer to run a complex operating system.

In 1970, Thompson wrote a programming language called B, which was the basis of the Basic Combined Programming Language (BCPL). Dennis Ritchie then wrote another programming language based on B, calling it "C" in the spirit of Thompson's philosophy of simplicity.

In 1972, Thompson rewrote Unix in C, which made it more portable and therefore successful. After he published his operating system, he returned to the university as a visiting professor. A lot of changes in the computer industry followed, and many start-ups such as Solaris, HP-UX, and AIX used Unix. Several functions in Unix worked well for start-ups, the most important being that it was designed to handle multiple users connected to a single network so they could share information. So, the Unix operating system had a great impact not only on computer science, but also in the business and scientific sectors.

In 1983, after Thompson became a fellow at Bell Labs, he kept working on new operating systems, such as Plan 9 and Inferno, also with Ritchie. For this and other great achievements, Thompson and Ritchie were awarded the U.S. National Medal of Technology as Unix inventors in 1998. Thompson also won the IEEE Richard W. Hamming Medal in 1990; he was made a fellow of the Computer History Museum in 1997 and won the Tsutomu Kanai Award in 1999 and Japan Prize in 2011.

After he retired from Bell Labs in 2000, Thompson moved to California and worked at Google as a distinguished engineer.

Rosanne Welch

See also Google; *Vol. 3, Sec. 2*: Ritchie, Dennis

Further Reading

Binstock, Andrew. 2011. "Interview with Ken Thompson." Dr. Dobb's. May 18. <http://www.drdoobs.com/open-source/interview-with-ken-thompson/229502480>, accessed August 31, 2018.

Khamlichi, M. "Ken Thompson UNIX Systems Father." <https://www.unixmen.com/ken-thompson-unix-systems-father/>, accessed August 31, 2018.

"Unix of Ken Thompson." <http://history-computer.com/ModernComputer/Software/Unix.html>, accessed August 31, 2018.

Primary Document: Interview with Ken Thompson, Inventor of the UNIX System (2011)

This interview with Ken Thompson, inventor of the Unix operating system, was conducted by Andrew Binstock of the Open Source section of the Dr.

Dobb's Web site after the ceremony presenting Thompson with the Japan Prize, which showed the international importance of Unix. They also discuss

Thompson's work designing the Go language for Google and how he collaborated with Dennis Ritchie and Ritchie's role in developing Unix.

Interview with Ken Thompson

By Andrew Binstock, May 18, 2011

The creator of UNIX discusses writing UNIX, the Go language, and collaborating with Dennis Ritchie

The Japan Prize, one of the highest honors awarded for outstanding contribution to science and technology, was awarded jointly this year to Ken Thompson and Dennis Ritchie for the creation of UNIX. The prize is normally given to the recipients at a lavish banquet in Tokyo attended by the emperor. However, due to the April earthquake and tsunami, the prizes this year were distributed at the honorees' place of work. I was able to attend the ceremony for Ken Thompson, held at Google headquarters, where he currently works. After the ceremony, he consented to this exclusive interview.

DDJ: Congratulations on winning this prize.

KT: Thanks.

Developing UNIX

DDJ: You've received a lot of awards over the years for UNIX. At what point in UNIX's development did it become clear it was going to be something much bigger than you'd anticipated?

KT: The actual magnitude, that no one could have guessed. I gather it's still growing now. I thought it would be useful to essentially anybody like me because it was not built for someone else or some third party. That was a pejorative term then. It was written for Dennis and me and our group to do its work. And I think it would have been useful to anybody who did the kind of work that we did. And therefore, I always thought it was something really good that was going to take off.

Especially the language [C]. The language grew up with one of the rewritings of the system and, as such, it became perfect for writing systems. We would change it daily as we ran into trouble building UNIX out of the language and we'd modify it for our needs.

DDJ: A symbiosis of sorts . . .

KT: Yeah. It became the perfect language for what it was designed to do. I always thought the language and the system were widely applicable.

DDJ: In the presentation today, it mentioned that UNIX was open source. Was UNIX open source from the beginning?

KT: Well there was no such term as "open source" then.

DDJ: I was under the impression that UNIX really became open source with the Berkeley distribution.

KT: No, we charged \$100, which was essentially the reproduction cost of the tape, and then send it out. And we distributed, oh, probably close to 100 copies to universities and others.

Go Language

DDJ: Skipping several decades of work, let's speak about Go. I was just at the Google I/O Conference, where it was announced that Go will be supported on the Google App Engine. Does that presage a wider adoption of Go within Google, or is it still experimental?

KT: It's expanding every day and not being forced down anybody's throat. It's hard to adopt it to a project inside of Google because of the learning curve. It's brand new and there aren't good manuals for it, except what's on the Web. And then, of course, its label of being experimental, so people are a little afraid. In spite of that, it's growing very fast inside of Google.

DDJ: In the presentation before the awarding of the Japan Prize today, you were quoted on the distinction between research and development. [The former, Thompson stated, was directionless, whereas development had a specific goal in mind.] So in that context, is Go experimental?

KT: Yes. When the three of us [Thompson, Rob Pike, and Robert Griesemer] got started, it was pure research. The three of us got together and decided that we hated C++. [laughter]

DDJ: I think there'd be a lot of people who are with you on that.

KT: It's too complex. And going back, if we'd thought of it, we'd have done an object-oriented version of C back in the old days.

DDJ: You're saying you would have?

KT: Yes, but we were not evangelists of object orientation. [Returning to Go,] we started off with the idea that all three of us had to be talked into every feature in the language, so there was no extraneous garbage put into the language for any reason.

DDJ: It's a lean language, indeed.

Collaboration with Dennis Ritchie

DDJ: Returning to UNIX, for a moment, when you and Dennis worked together, how did that collaboration operate? Were you working side by side?

KT: I did the first of two or three versions of UNIX all alone. And Dennis became an evangelist. Then there was a rewrite in a higher-level language that would come to be called C. He worked mostly on the language and on the I/O system, and I worked on all the rest of the operating system. That was for the PDP-11, which was serendipitous, because that was the computer that took over the academic community.

DDJ: Right.

KT: We collaborated every day. There was a lunch that we went to. And we'd talk over lunch. Then, at night, we each worked from our separate homes but we were in constant communication. In those days, we had mail and writ (pronounced 'write'), and writ would pop up on your screen and say there was a message from so-and-so.

DDJ: So, IM essentially.

KT: Yes, IM. There was no doubt about that! And we discussed things from home with writ. We worked

very well together and didn't collaborate a lot except to decide who was going to do what. Then we'd run and very independently do separate things. Rarely did we ever work on the same thing.

DDJ: Was there any concept of looking at each other's code or doing code reviews?

KT: [Shaking head] We were all pretty good coders.

DDJ: I suspect you probably were! [Laughter]

SCM

DDJ: Did you use any kind of source code management product when working together?

KT: No, those products really came later; after UNIX. We had something like it, which we called "the code motel" because you could check your code in but you couldn't check it out! So, really, no we didn't.

DDJ: I bet you use SCM today in your work on Go.

KT: Oh, yes, Google makes us do that!

Source: Dr. Dobbs, the World of Software Development. <http://www.drdobbs.com/open-source/interview-with-ken-thompson/229502480>, accessed September 26, 2018.

3-D Printing

3-D printing is the process of creating a three-dimensional object from a template originally designed using a computer program and formed by applying thin layers of material onto one another in quick succession. Objects can be printed in almost any shape or geometry. Another term for 3-D printing is "additive manufacturing" (AM). This is the official term used by the United States and global technical standards to encompass the wide variety of techniques. There are seven defined categories of additive manufacturing processes: binder jetting, directed energy deposition, material extrusion, material jetting, powder bed fusion, sheet lamination, and vat photopolymerization.

Additive manufacturing began in the 1980s when Hideo Kodama of Nagoya Municipal Industrial Research Institute invented methods for fabricating plastic models with photo-hardening polymer by a means of UV exposure controlled by a mask pattern.

In 1984, Alain Le Méhauté, Olivier de Witte, and Jean Claude André filed a patent for this process, which was called "stereolithography." However, it was abandoned due to lack of business perspective. That same year, Chuck Hull of 3D Systems Corporation filed his own patent for the process. Hull's is known for his STL (stereolithography) file format and digital slicing and infill strategies. This method is still used in almost all processes today.

Scott Crump later developed fused-deposition modeling (FDM) in 1988, which involves a special application of plastic extrusion. This is the most common hobbyist and consumer-oriented process. Crump's company, Stratasys, commercialized this process and marketed the first FDM machine in 1992. Since then, metal sintering or melting has been developed along with many other AM techniques.

3-D printing uses three general principles. Modeling, the first principle, uses a computer-aided design (CAD) package, plus a 3-D scanner or a plain digital camera and photogrammetry software. CAD models

have the inherent benefit of reduced error and can be corrected before printing. Printing is the second principle and involves several steps. First, an STL file is created from the CAD model, which is processed into several layers using software, called a “slicer,” into a G-code. The G-code file can then be printed. Printer resolution is described by the layer thickness and X-Y resolution in dots per inch (dpi) or micrometers (μm). The final principle in 3-D printing is finishing. Finishing involves cleaning up the final build. “Final build” describes the entire print created by the machine, including the part and all support material used by the printer. Finishing involves the process of removing build supports, smoothing surfaces, or any other final work done to a 3-D printed object.

The main differences between the various AM processes is the way that layers are deposited to create the specific part. One of the main methods melts or softens the material to produce the layers. This method is known as “fused filament fabrication,” another term for FDM. FDM parts are built by the extruding of small beads or streams of material that harden immediately into a layer. Filaments consist of thermoplastic, metal wire, or other material that can be fed into an extrusion nozzle. FDM is restricted in the variation of shapes due to the build method. The nozzle lays a layer of material down and then moves upward in the working area. This leaves the next layer unsupported on overhangs so that the nozzle is printing on air instead of on top of another layer.

Laser sintering techniques include selective laser sintering and direct metal laser sintering. Selective laser melting completely melts metal powder using a high-energy laser; this creates a dense material. Its mechanical properties are similar to conventional manufactured metals. Electron beam melting (EBM) is a similar technique used for metal parts such as titanium alloys. EBM works by melting metal powder with an electron beam in a high vacuum. A thin layer of metal powder is raked off the previous layer, and the electron beam melts the powder into the desired design. This leaves a metal “cake” at completion of the build that needs to go through a finishing process to remove all remaining unfused powder.

Photopolymerization is another type of AM process that produces a solid part from a liquid polymer.

This requires a special type of photopolymer that is cured with UV light. Ultrafine details can be created with this method because the gel is cured to a solid only in the location where the laser is focused. All other gel is washed away. The continuous liquid interface production begins with a vat of photopolymer resin, with the bottom of the vat being transparent to expose the material to UV light. The object is slowly pulled out of the vat layer by layer.

AM has many applications and uses in all different fields of study. Today it is used in industries such as aerospace, architecture, automotive, defense, and medical replacement. The earliest application and most common is rapid prototyping, which allows a reduced lead time and cost of developing prototypes for new parts and devices. In the 2010s, AM entered the production phase for industry. Many companies are looking into the quality and certification of AM parts for production, such as General Electric, which uses high-end AM to build parts for turbines. It is believed that with certification of AM, the complexity of parts can be increased to reduce material, weight, lead time, and cost. This would also reduce maintenance time for replacement parts due to the rapid production time. The medical field is also looking into bioprinting technology, which involves printing layers of living cells into a gel medium to build organs, including vascular systems, with a patient’s own cells. 3-D printing has also improved STEM education due to low cost and high-quality equipment for students.

AM has many applications and benefits but is still in the research stages. Developing the test standards and certification of parts seems to be the biggest challenge faced by industry.

Nicole Curtis-Brown

See also *Maker Faire*; *Vol. 1, Sec. 3: Printing*; *Vol. 3, Sec. 2: Computer/Information Technology*; *Digital Photography*; *Genetic Engineering*

Further Reading

- Andrew, Philip. 2017. “Additive Manufacturing.” *Mechanical Engineering* 139, no. 3: 55–56.
- Gibson, I., et al. 2010. *Additive Manufacturing Technologies: Rapid Prototyping to Direct Digital Manufacturing*. New York: Springer.

3G Network. See Smartphone and 3G Network

TOR (The Onion Router)

The Onion Router, more commonly known by its acronym, TOR (or Tor), is free anonymizer software. Tor increases anonymity when sending and receiving packets through its network at the expense of packet-sending speed. Tor is free to access and requires a specialized browser, available for free online, to connect to the network.

The Tor network uses an implementation of onion routing, which encrypts a packet with several layers and then bounces the data across randomized servers in the Tor network. Each of these servers uses its own asymmetric encryption, by which the packet is encrypted layer by layer by the user. As the packet traverses the Tor network, each server decrypts the layer it is responsible for and forwards it to the next node; therefore, any individual server does not know the contents of a packet and only knows the server that forwarded the packet to it and the server that it will forward the packet to, allowing for more secure packet sending at the expense of response time. This continues until the packet reaches a Tor exit node, where the packet is fully decrypted and sent to its end server. Due to the number of nodes being relayed through, while it is still possible, it is highly unlikely for someone to be able to pinpoint the origin of a packet sent.

The Onion Router was first released by the U.S. Naval Research Laboratory on September 20, 2002. This Tor was originally based on a paper done by Cambridge researchers in 1996 on packet hiding, eventually leading to the development of onion routing. The Tor network has servers run by volunteers around the globe, numbering in the thousands by 2017.

Today, the Tor network increases anonymity for end users and end servers as well. There are specific domains accessible only through the Tor network. Top-level domain names under “.onion” are onion links accessible only through Tor browsers. These sites reply with packets that are also sent through the

same Tor network, making it difficult to track the origin of the Web sites and shut them down. Due to this nature, Tor is home to many licit and illicit usages. This includes sites that offer free books, political activism, drug trafficking, illegal gambling, and more. Many of these services are often used in conjunction with BitCoin to maintain anonymity online through the use of cryptocurrency.

Tor provides refuge for both censored information and illegal trafficking. Law enforcement has been successful in tracking down several users due to mistakes by end users that break their anonymity. Since Tor exit nodes are publicly listed, it is possible to eavesdrop on a Tor exit node that is not properly secured with end-to-end encryption, resulting in possible leakage of user-related information such as e-mails and passwords.

Emma E. L. Burke

See also Amazon.com; Google

Further Reading

- Goldschlag, David M., Michael G. Reed, and Paul F. Syverson. 1996. “Hiding Routing Information.” Workshop on Information Hiding. Cambridge, UK. May. <https://www.onion-router.net/Publications/IH-1996.pdf>, accessed August 31, 2018.
- Reed, Michael G., Paul F. Syverson, and David M. Goldschlag. 1997. “Anonymous Connections and Onion Routing.” Naval Research Laboratory. <https://www.onion-router.net/Publications/JSAC-1998.pdf>, accessed August 31, 2018.

Torvalds, Linus (1969–)

Linus Torvalds is a software engineer who created the Linux kernel operating system. Because he wrote Linux at the age of 21, people called him a creative genius. Linux is freely available and has had a great impact on the development of shared software and networking. Since its creation more than 20 years ago, Linux has become the world’s most ubiquitous operating system. It has had a great deal of influence on most tech companies, such as Amazon, Facebook, Google, and Twitter. Torvalds became one of the most famous

software programmers, listed several times in *TIME* magazine’s “Most Important People of the Century.” He has won many awards, including the Millennium Technology Prize, one of the largest prizes in the computer field.

Torvalds was born in Helsinki, Finland, on December 28, 1969. When his parents divorced, he lived with his mother and grandparents. Because his mother worked, he spent most of his time with his grandparents. Many in his family were journalists, which influenced him to read a lot, and when he was 11 years old, he started using a computer. His grandfather was a professor of statistics at Helsinki University, so he began using a computer as a programmable calculator.

Torvalds attended the Helsinki University of Technology, where he learned engineering-oriented computer science. He started working on Linux in spring 1991 after learning about Unix and the C language. Wanting to study Unix, he purchased the Intel 80386-based IBM PC and obtained a MINIX operating system to work with. From there, he developed the Linux operating system. It took eight years for Torvalds to receive his master’s degree in computer science since he had a vibrant social life and because universities are essentially free in Finland, so he didn’t have to worry about its costs. But because he did not want to stay in school forever, he thought about his future and went to the United States.

In 1996, he visited the technology firm Transmeta and joined it the following year. He felt he could do something great there. He worked in a group called the 86open from 1997 to 1999, creating binary compatibility across all Unix variants on Intel architecture. In other words, the group focused on building a single application that ran on all Intel-based Unix machines. After he finished the project, he was offered stock options for his creation by the companies Red Hat and VA Linux. After these companies went public, the stocks’ value increased to about \$20 million. In 2006, Torvalds wrote about 2 percent of the Linux kernel, which was a high achievement. And because the Linux kernel is open source, other programmers contributed to write the rest of it. Torvalds received the Millennium Technology Prize in 2012 for his achievements.

In 1993, Torvalds married Tove Torvalds, who was a six-time Finnish national karate champion. They

have three daughters: Patricia Miranda, Daniela Yolanda, and Celeste Amanda. He wanted his daughters to get a good education in the United States. He has said that he is very happy in the United States because his family is. He may be one of the greatest computer scientists in the world, but he is also just a father who loves his family.

Rosanne Welch

See also Amazon.com; Facebook; Google

Further Reading

- Brashares Ann. 2001. *Linus Torvalds, Software Rebel*. n.p.: 21st Century.
- Noyes, Katherine. 2012. “Top Honor for Linus Torvalds Highlights Linux’s Importance.” PCworld.com. April 19. http://www.pcworld.com/article/254089/top_honor_for_linus_torvalds_highlights_linuxs_importance.html, accessed August 31, 2018.
- Perens, Bruce. 1997. “Unix-on-Intel Players Work on a Common Binary Format.” Debian.org. October 10. <https://lists.debian.org/debian-announce/1997/msg00028.html>, accessed August 31, 2018.

Tyson, Neil deGrasse (1958–)

Astrophysicist, science communicator, and author Neil deGrasse Tyson has authored more than 10 books, his most recent being *Astrophysics for People in a Hurry* (2017). Tyson’s books discuss many areas of science in a whimsical and accessible way for the public. His accolades include the NASA Distinguished Public Service Medal and the Public Welfare Medal. Most of his work is focused on astronomy, cosmology, stellar formations, and stellar evolution. He has received much recognition at the government level as well. In 2001, President Bush selected him to be on commission for future advancements in the United States aerospace industry.

Tyson became a household name in 2004 when he hosted a four-part mini television series titled *NOVA: Origins*. In it, Tyson attempted to convey how the universe came to be and where it may be headed in both an interesting and accessible way. Three years later, in



Among the best known public scientists of the 21st century, astrophysicist Neil deGrasse Tyson is a powerful voice for climate change, science education, and space exploration. (Rick Kern/WireImage/Getty Images)

2007, he became a regular contributor on the television series *The Universe* on the History Channel.

Tyson was born on October 5, 1958, and grew up attending public schools in the Bronx neighborhood of New York City. He attended several colleges in the United States, earning a bachelor of science in physics at Harvard University in 1980 and a PhD in astrophysics in 1989 at Columbia University. At age nine, he visited the world-renowned Hayden Planetarium at the Rose Center for Earth and Space in New York City, and his fascination for astronomy began. The center is part of the American Museum of Natural History, and in 1996, Tyson became the fifth head of the Hayden Planetarium. A year later, he founded the Department of Astrophysics at the Museum of Natural History.

Tyson is often linked with late astronomer and cosmologist Carl Sagan. When Tyson was 17, Sagan took him around the Cornell University campus and

gave him a book with an inscription to “the future astronomer.” Tyson has been open about how much this experience with Sagan influenced his life and passion for astronomy. Sagan is famous for a television series that appeared in 1980 and inspired its audience’s fascination with the universe and its beauty. In fact, in 2014, Tyson revived Carl Sagan’s *Cosmos: A Personal Voyage* series through his *Cosmos: A Spacetime Odyssey*. Tyson attempts to inspire passion for the universe the same way Sagan did in his generation. *Cosmos: A Spacetime Odyssey* won many awards, including a Peabody, four Emmys, and two Critics Choice Awards.

Tyson continues to be an active contributor to the astronomy field. He lives in Manhattan with his wife, Alice Young (they married in 1988), and their two children, Miranda and Travis.

Lydia Nolte

See also *Vol. 3, Sec. 1*: Apollo Project; National Aeronautics and Space Administration (NASA); *Vol. 3, Sec. 2*: Space Shuttle

Further Reading

Tyson, Neil deGrasse. 2004. *The Sky Is Not the Limit: Adventures of an Urban Astrophysicist*. New York: Prometheus Books.

Tyson, Neil deGrasse. 2017. *Astrophysics for People in a Hurry*. New York: W. W. Norton.

Video Game

A video game is an electronic game in which a user interacts with an input device to generate visual feedback on a television screen, computer, or handheld or cellular device. Video games are played on electronic systems, and many of these systems are known as “platforms.” Platforms can differ between computers, gaming consoles, handheld devices, cellular phones, arcade machines, and so on. Due to the affordability of gaming consoles, there has been a decline in the popularity of arcade machines. Gaming consoles can also offer the advantage of being all-in-one entertainment media centers.

Video games use different input devices to generate visual feedback. The input device used is called a gaming controller and can differ between platforms. Common gaming controllers include gamepads, joysticks, keyboards, steering wheels, touch screens, buttons, or visual sensors—even a person’s own body.

Video games are not only visual but also incorporate music, vibration, and story to immerse the user. Users can also wear virtual reality goggles to allow a full immersion into a video game.

Commercial video games first started to appear in the 1970s, but the earliest evidence of a video game dates back to 1947. Video games became very popular with the success of the Atari home console system and the video game *Pong*. Video games soon thereafter left the arcade and began to enter the home as video game platforms became more affordable. Video game consoles now offer more features than just games. Video game platforms or consoles include DVD capabilities,

applications, and online video streaming. They have become all-in-one entertainment devices.

A “platform” is the combination of electronic hardware and software for playing video games. The term “system” can also be used instead of platform. Other important vocabulary in the video game world includes:

- *Personal computers or PCs*, which can be used as platforms to play a video game. A video game may be referred to as a “computer game” to convey that it is played on a PC. Personal computers offer some advantages over other platforms, which may include online gaming, modding, flexibility, emulation, and cost.
- *Consoles*, which are platforms on which video games can be played. Consoles offer the advantage of being home entertainment centers or media centers for the user.
- *Handheld* platforms are small and lightweight. They offer a mobile gaming experience.
- *Arcade* machines are platforms that were mainly popular during the 1980s and have slowly been replaced by consoles. Arcade machines each usually feature only one type of game and can sometimes involve prizes.
- *Mobile* platforms have been increasingly popular due to the rise of cellular phones. Mobile games are usually featured on iOS or Android devices.
- *Virtual reality* headsets are used to experience a fully immersive environment.
- *Genres*. Video games, just like movies, come in different genres offering different experiences and are based on gameplay rather than story or setting.
- *Controllers* are input devices to transmit the user’s actions or intentions into the video game. Controllers differ based on platform. The most widely used controllers are keyboards, mice, gamepads, buttons, or touch screens. Controllers can also be for very specific purposes such as driving wheels, dance pads, or joysticks.
- *Development*. Video game developer roles have increased as video games have become more popular.

In the early days of video games, a single developer would create every element of a game. While this

is still common for small or mobile games, most games are now the products of large development studios. The roles of video game developers can include programmer, graphic designer, sound designer, musician, producer, and so on. The development of games can continue past the games' release date as more content can be made available via download, which can include new story lines, game features, or settings.

Some video games also allow modifications to be made to the game to add new features or interest. Modifications have become extremely popular in PC games and may contribute to the success of a game. Game developers have also created development tools to assist the video game community in creating modifications. In some cases, the modifications of certain video games have led to the creation of entirely new video games.

Glitches are errors that were not detected during testing and end up in the released versions of the video game. Glitches can range from game exploitations, game malfunctions, or minor errors. Glitches are usually reversed in future updates or become additional game features.

Easter eggs are hidden messages, jokes, games, or signatures left by the developers within the game. Easter eggs are often kept hidden by the developers and are left to be found by the video game community.

Emulations are software programs that allow video games to be run on different hardware than the originally intended console. Emulators can be used on PCs, smartphones, and consoles. Video game manufacturers have also made their own emulators to combat video game piracy.

While the main demographic of video gamers have been men, the gap between women and men gamers has decreased. Women over the age of 18 are becoming one of the fastest-growing demographics within the video game community. As video games become more popular, they are also becoming part of pop culture. Video games have also spawned online communities, competitive tournaments, art, and entertainment. Video games are often played with others and are a social experience. Arcade machines traditionally allowed up to two players, and consoles expanded the experience by allowing four players. With the Internet, players can now play with extremely high numbers of people.

Video game players have been shown to have better hand-eye coordination, visuomotor skills, resistance to distractions, and ability to decipher objects or situations than their nonplayer counterparts. Video games are usually more demanding than traditional board games, and a player must first learn how to operate the proper game controls and interfaces. The way learning is approached in games has been adopted by different education systems and promotes a hands-on approach to learning. Other possible benefits of playing video games are that it helps promote self-esteem, relieve stress, and promote social interaction between players.

Due to adult content such as sex, violence, drug use, profanity, and criminal activity, video games have received backlash from parents, religious groups, and advocacy groups. Video games are given ratings based on content within games similar to how a movie is a rated. In the United States, the Entertainment Software Rating Board (ESRB) rates games based on their content. In Europe, the Pan European Game Information (PEGI) system was created to rate games similar to the ESRB.

Electronic sports, also known as e-sports, have gained immense popularity. Fighting, first-person shooters, multiplayer battle online arenas, and real-time strategy games have become the most common types of video games to appear in e-sports. Players compete with one another in tournaments, and cash prizes have been as high as \$24 million. Players that compete are often referred to as professionals. The U.S. government also recognizes e-sports players as professional athletes. The main medium for viewing e-sports has been Internet live streaming; however, media networks such as ESPN have also displayed e-sports.

William E. Balsells

See also Blizzard Entertainment; Smartphone and 3G Network; Video Streaming Services; Virtual Reality (VR); YouTube

Further Reading

Gee, James Paul. 2008. *What Video Games Have to Teach Us about Learning and Literacy*. London: Palgrave Macmillan.

Hansen, Dustin. 2016. *Game On!: Video Game History from Pong and Pac-Man to Mario, Minecraft, and More*. n.p.: Feiwei & Friends.

Rogers, Scott. 2014. *Level Up!: The Guide to Great Video Game Design*. New York: Wiley.

Video Streaming Services

Video streaming services allow the user to watch an active stream of video over the Internet. In the past, a user had to download a video to watch it. Streaming is a delivery medium that allows viewers watch video that has not downloaded (a process that forces users to electronically obtain the entire file before opening it for any purpose). YouTube and Netflix are popular streaming content providers.

YouTube was invented by Steve Chen, Chad Hurley, and Jawed Karim. The three were coworkers at PayPal. Karim says their inspiration for the idea came after the Super Bowl halftime incident in which Janet Jackson revealed her breast. Karim was searching for a video of the incident but could not find one online. This gave them the idea of creating a video sharing site. YouTube was activated on February 14, 2005, and the first video was uploaded in April 2005. Chen, Hurley, and Karim sold YouTube to Google for \$1.6 billion on October 9, 2006.

After YouTube was created, Netflix expanded from a DVD delivery service to a streaming media service by providing instant online access to a variety of movies. Along with Netflix in 2007, Apple TV appeared, and in 2008, Hulu launched. Because so many streaming media sites are available, it has become popular to cancel cable subscriptions and instead hook up smart TVs to Netflix, YouTube, Amazon, and Hulu, and so on. Having instant, online access to a variety of TV shows and movies has taken priority over a cabinet full of DVDs.

Video streaming has grown into live video streaming. In 2011, Twitch.tv was launched as a platform for video gamers to video themselves live and interact with other gamers. By 2015, Twitch had about 100 million visitors per month and over 1.5 million broadcasters. In 2017, Twitch launched an “In Real Life” channel where people video themselves live doing just

about anything. In August 2015, Facebook released its live video feature to select celebrity users. Facebook Live launched publicly in September 2016. On September 26, 2016, Facebook teamed up with ABC to stream the Donald Trump debate versus Hillary Clinton via Facebook Live. Over 28 million people tuned in live, and so Facebook Live was put on the national radar.

Chelsea Kirkpatrick

See also Amazon Web Services; Facebook; Google; iPod; Java; PayPal; Smartphone and 3G Network; YouTube

Further Reading

Bing, Benny. 2015. *Next-Generation Video Coding and Streaming*. Hoboken, NJ: John Wiley & Sons.

Pathan, Mukaddim, Dom Robinson, and Ramesh K. Sitaraman. 2014. *Advanced Content Delivery, Streaming, and Cloud Services (Wiley Series on Parallel and Distributed Computing)*. Hoboken, NJ: John Wiley & Sons.

Smith, Michael D., and Rahul Telang. 2016. *Streaming, Sharing, Stealing: Big Data and the Future of Entertainment*. Cambridge: Massachusetts Institute of Technology.

Virtual Reality (VR)

Virtual Reality (VR) is a simulation of a three-dimensional environment created by electronic equipment. It attempts to create the feeling of virtual presence—the impression that the user is actually present in a virtual environment. A virtual environment is a three-dimensional, 360-degree space generated by a computer. Audio is almost always included in these experiences and used both for sound effects and as music. Creating other kinds of sensations such as touch is less common, but it is being developed. Usually, one looks around the virtual area, interacts with objects, and moves through the space by moving one’s body much as one would in the physical world.

There are several devices commonly used to create these environments. Goggle-like headsets cover a user’s eyes, taking advantage of parallax to create the

illusion of three-dimensionality. These headsets may include speakers, or separate headphones may be used. Headphones often have stereo sound to increase immersion in the artificial environment. Developers are working on tactile feedback to recreate the feeling of touching objects. In certain VR parks, it is possible to have a physical room mirror the virtual environment, so a rock in game will physically exist in reality, but this is not practical for use in the home. So far, most tactile feedback is limited to vibrating controllers. Research is looking into improving feedback for all senses.

The degree and method of interactivity may vary from system to system. The most common feature is the ability to “look around” in these environments. The image projected will react to users moving their heads, mirroring the visual changes that would be expected in the real world. A user’s movement through virtual space may be manipulated by remote controllers, a camera may pick up the user as they walk through a room in real life and mirror that motion in the space, or a multidirectional treadmill may be used to track movement. Controllers can also be used to interact with virtual objects. Some newer devices can pick up the motion of a controller in space, and so a user can move the controller in real life to interact with an object in the virtual space. Ideally, developers want devices that allow users to interact with virtual environments as naturally as possible.

As the technology for VR is still being developed, there remain many issues. The system can be a hassle to get set up, discouraging casual consumers. Headsets are often heavy and cumbersome, as they must be connected with wires to a computer. Price may also be an obstacle to widespread commercial use, though the cost has gone down in recent years. It should be noted that in addition to the cost of the system itself, a computer capable of running VR will likely run over a thousand dollars. In fact, most computers are not able to run VR systems at all, due to the intense graphical processing required. This intense processing also limits picture quality and the system’s reaction time.

One of the biggest issues is that many people become nauseated while using VR. In both video games and VR, movement may be shown on screen, but if the user is not moving this may cause nausea.

However, nausea may be even worse in VR. It is worsened by delayed reaction time from VR devices, which creates a disconnect between user actions and the visual output. Refresh rate—how often a display changes frames—is still low compared to most video games. This decreases visual quality and increases the chance that someone will become nauseated.

There are numerous other potential applications for VR, from entertainment to the practical. For example, VR can replicate the feeling of watching a movie on a theater-size screen or allow one to watch a three-dimensional movie, one that a user can look around and see from different angles. Another application is in social interactions, such as creating a three-dimensional videoconference. A more practical use is in training, especially for things that may be dangerous or impossible to train for in real life. Simulations are often used to train pilots and soldiers, and more kinds of VR training may be seen in the future. VR exposure therapy for public speaking may be just as effective as group therapy, and as the technology becomes more available, it may be a cheaper and more convenient alternative. Other applications may be considered in the future as well.

Currently, the most common use for VR is video games, and most systems commercially available are focused on games. The idea of a three-dimensional, interactive environment fits right in with video games, which try their best to represent these kinds of environments on a flat screen. Video games often desire greater immersion for players, and VR can offer a step in that direction by allowing three-dimensional environments to actually appear three-dimensional. Eventually, one may be able to interact with virtual environments as if one is really there. This appeals to many adventure-seeking gamers.

As recently as five years ago, there were no commercially available VR devices, but this is quickly changing. In the past couple of years, VR has become affordable enough for individual buyer, though prices are still in the hundreds of dollars. Today, there are several commercially available VR products.

The Oculus Rift became available in March 2016 and is currently focused on gaming, but it offers other applications as well. It uses the headset itself as a controller—for example, one looks at a menu option

for a few seconds to select it, or controls a paddle in a 3-D version of *Pong* by moving one's head. Control is sometimes supplemented with a video game controller, which is necessary for games that require more complex controls. The Vive's release marked a renewed interest in the field of VR.

The HTC Vive was released by the gaming company Steam in April 2016 and is almost exclusively for games. It creates virtual rooms that match the dimension of the real room a user is in. Then it tracks their movement within the real room to move them through the virtual one. The Vive also comes with two controllers that track movement and are used to interact with objects and perform other commands. Many consider the Vive the best commercially available VR system at the moment.

Intel, meanwhile, is working on technology specifically aimed at alleviating some of the problems with VR through Project Alloy. Rather than working on a specific device, Intel intends to work with different hardware manufacturers to create several different headsets. Alloy has a feature called “inside-out tracking,” meaning that the headset tracks itself rather than being tracked by some outside device. This helps reduce the complexity of setup for the user. The headset will be wireless, eliminating the problem of tripping on wires. It has a camera that makes a 3-D map of the room the user is in automatically, unlike the Vive, which must be set up by the user. It can even take into account objects inside a room, turning a table into a fountain, for example.

On the simpler end of things, Google Cardboard allows one to turn a smartphone into a rough VR headset by placing it in a cardboard head mount. This is not only extremely cheap but extremely easy to implement, making it by far the most accessible VR system. However, it lacks power compared to other devices. The controls are limited to moving the phone through space, and it seems it may mainly be for watching three-dimensional videos rather than playing games. Even the games that are available for it must be very simple. Its accessibility is its main asset, allowing just about anyone with a smartphone to experience VR.

With the rush of development in the past few years, it seems likely that VR will gain popularity going forward. Not only are new systems being

released, but developers will have more time to release applications for those systems. Devices are becoming smaller, lighter, and easier to use. Newer devices also have better tracking, leading to less motion sickness. As developers work out the problems and new products are released, prices will fall, and more people will be drawn to VR. Some predict that in the not-too-distant future, VR will be commonplace.

Jenna Barrett

See also Joystick/Flight Simulator; Video Game; *Vol. 3, Sec. 2: Personal Computer (PC)*

Further Reading

- Anderson, Page, Matthew Price, Shannan Edwards, Mayowa Obasaju, Stefan Schmertz, Elana Zimand, Martha Calamaras, and Arthur M. Nezu. 2013. “Virtual Reality Exposure Therapy for Social Anxiety Disorder: A Randomized Controlled Trial.” *Journal of Consulting and Clinical Psychology* 81, no. 5: 751–60.
- Chorafas, Dimitris N., and Heinrich Steinmann. 1995. *Virtual Reality: Practical Applications in Business and Industry*. Englewood Cliffs, NJ: Prentice Hall PTR.
- Henneberg, Susan. 2017. *Virtual Reality*. New York: Greenhaven.
- Pimentel, Ken, and Kevin Teixeira. 1993. *Virtual Reality: Through the New Looking Glass*. New York: Intel/Windcrest.

Wang, An (1920–1990)

An Wang, a Chinese-born American inventor, engineer, and business executive, built important inventions relating to computer memory and electronic calculators. He founded Wang Laboratories Inc. and served as its executive officer. It was a leading American manufacturer of computers and word-processing systems.

Wang was born on February 7, 1920, in Shanghai, China. He learned English at home from his father before beginning formal schooling at the age of six, when he started the third grade. In high school, he developed an interest in radio and built his own radio

unit. He then entered Chiao-Tung University in Shanghai, where he studied communications engineering. With the start of World War II and the Japanese invasion of China, Wang left Shanghai for inland China, where he designed radio receivers and transmitters for use by the Chinese military.

Wang came to the United States in 1945, where he entered Harvard University in Cambridge, Massachusetts. Funded by a stipend from the Chinese government, Wang completed his master's degree in communications engineering in one year. After working briefly for an American company, Wang took a position with the Canadian office of the Chinese government. In 1947, he returned to Harvard and quickly completed his doctorate degree in engineering and applied physics. In 1949, Wang married, and he and his wife had three children. Wang became an American citizen in 1955.

In 1948, Howard Aiken hired Wang to work at the Harvard Computation Laboratory. Aiken tasked Wang to develop a system for retrieving and storing data in a computer by using magnetic devices. Wang focused his research on the magnetic properties of small, doughnut-shaped rings of ferromagnetic material, which were capable of becoming highly magnetized. Wang soon developed a process whereby data stored on one of these rings could be read by running a current around it.

Researchers at the Massachusetts Institute of Technology (MIT) were also interested in the idea of magnetic core storage of data and had developed it for use in various computers. In a 1950 article coauthored with another Shanghai-born scientist at Harvard, W. D. Woo, Wang announced the results of his work. He patented his invention and, despite a long court fight, earned substantial royalties from International Business Machines (IBM) and other computer manufacturers who used his magnetic core memories as a basic part of computers into the 1970s.

Unhappy that others were profiting from the development and sales of his inventions, Wang left the Computation Laboratory in 1951 and used his life savings to start his own company. Wang Laboratories built and sold a number of products, including custom-built magnetic shift registers for storing and combining electronic signals, and devices for magnetic

tape and numerical control. In the mid-1960s, Wang invented a digital logarithmic converter—a desktop calculator—that allowed people to electronically perform routine arithmetic calculations at high speed and relatively low cost. Desktop calculators soon replaced the traditional machines with mechanical parts and one processing unit. Wang soon saw that the introduction of other technology would permit competitors to sell electronic handheld calculators at much lower prices.

Confronted with the need to find new products, Wang focused his company's efforts on the manufacture of word processors and small business computers. The devices were designed for easy access by those unfamiliar with computers, for broad database management, and for routine business calculations.

By the mid-1980s, Wang Laboratories, which had begun in a room above an electrical fixtures store in Boston, employed over 15,000 people working in several buildings in the manufacturing town of Lowell, Massachusetts, and in other factories and offices throughout the world.

In 1982, Wang Laboratories generated more than \$1 billion per year; by 1989, sales were as high as \$3 billion a year. Wang died of cancer in March 1990 at the age of 70; the company fell on hard times in the early 1990s, when it filed for Chapter 11 Bankruptcy.

Wang's engineering insight and business success made him a fellow of the Institute of Electrical and Electronic Engineers and a fellow of the American Academy of Arts and Sciences. He received an honorary doctoral degree from the Lowell Technological Institute.

Rosanne Welch

See also Vol. 2, Sec. 3: MIT Radiation Laboratory

Further Reading

- Hargrove, Jim. 1993. *Dr. An Wang, Computer Pioneer*. Chicago: Children's Press.
- Kenney, Charles. 1992. *Riding the Runaway Horse: The Rise and Decline of Wang Laboratories*. Boston: Little, Brown.
- Pugh, E. W. 1984. *Memories That Shaped an Industry*. Cambridge, MA: MIT Press.

Williams, Roberta (1953–) and Ken (1954–)

Roberta and Ken Williams are known for being the founders of the video game developing and publishing company Sierra Entertainment Inc. At this company, the Williamses created the popular franchise *King's Quest*, which spanned up to 9 games, with the 10th game being a reboot that was released in 2015.

Roberta Williams was born on February 16, 1953, and raised in La Verne, California. When she was younger, she was said to have had “the greatest imagination of the 20th century.” Roberta Williams did not have any interest in video games or computers until she married Ken. In 1979, there were few adventure-style video games. Roberta wrote and created *Mystery House* with the help of her husband.

After the successful launch of *Mystery House*, Roberta started to create a new adventure video game

called *King's Quest*. It allowed the player the full ability to control the character, redefining the adventure video game genre. Most adventure computer games during this time were text based. The game sparked a popular series that included seven sequels and three companion novels. Due to this, Roberta was named the “queen of the graphic adventure.”

Ken was born on October 30, 1954, in Evansville, Indiana. After graduating high school a year early at the age of 16, he majored in physics in college. He became a computer programmer at the Control Data Institute trade school in Los Angeles, California. When Roberta had the idea for *Mystery House*, Ken aided her in the computer programming and coding aspects of the game. Ken used a Versawriter to create *Mystery House*. This machine allowed them to create a drawing placed on the screen of the machine, which was then traced by an arm. However, the files created by Versawriter were too large for to fit on the floppy



Roberta and Ken Williams, cofounders of Sierra On-Line, an American video game development company. (John Storey/The LIFE Images Collection/Getty Images)

discs of the time, so Ken began work on a better version of Versawriter before completing *Mystery House*. Once *Mystery House* was released and an ad was published for it in *Micro Magazine*, the game gained positive feedback. The couple (now the parents of two children) then decided to create a video game company.

Roberta and Ken Williams soon became cofounders of the video game development company Sierra Entertainment. It became one of the top consumer software companies, with a huge distribution of products across the world. Sierra Entertainment was sold in 1996, and Roberta and Ken Williams retired from the company in 1998.

Alan S. Peña

See also Blizzard Entertainment; Netscape; Video Game; Vol. 3, Sec. 1: Atari; Baer, Ralph

Further Reading

Hansen, Dustin. 2016. *Game On!: Video Game History from Pong and Pac-Man to Mario, Minecraft, and More*. n.p.: Feiwei & Friends.

Kent, Steve L. 2001. *The Ultimate History of Video Games: From Pong to Pokémon—The Story Behind the Craze That Touched Our Lives and Changed the World*. n.p.: Prima.

“Roberta Williams.” Lemelson-MIT. <http://lemelson.mit.edu/resources/roberta-williams>, accessed August 31, 2018.

“Roberta Williams.” Sierra Gamers. <http://www.sierragamers.com/roberta-williams>, accessed August 31, 2018.

Wireless Communication

Wireless communication, also referred to as “telecommunications,” refers to any mode of information transmission over a short or long distances without the use of wires, cables, or any other form of solid electrical conductor. The United Nations International Telecommunication Union similarly defines telecommunications as the transmission, emission, or reception of any signs, signals, or messages by means of electromagnetic systems. This can assume various forms, though

“wireless communication” is often used synonymously with “radio transmission,” with the medium being the lower or upper atmospheres, or space. First originating in the 19th century, wireless communication is now a keystone of modern society affecting all aspects of human life, ranging from instant intercontinental communication between governments and movements to social communication in interpersonal relationships. It has been cited as having made the world smaller, as people can be directly informed of affairs across the world that they would not be privy to in the absence of communications technology.

The inception of wireless communication began with Scottish scientist James Clerk Maxwell (1831–1879), who was the first to mathematically prove the existence of electromagnetic waves in 1865. In 1887, Heinrich Rodolf Hertz (1857–1894) first sent and received electromagnetic waves through a spark transmitter and resonator receiver, thus practically demonstrating Maxwell’s proof and the existence of radio waves.

However, the age of radio is often cited as beginning with Italian electrical engineer Guglielmo Marconi (1874–1937). Privately educated but showing immense interest in the research of Maxwell and Hertz, Marconi experimented with their theories on his father’s country estate at Pontecchio, managing to send and receive the first wireless Morse code signals over a distance of 1.5 miles in 1895. The next year, he transported his apparatus to England and filed the first patent for a system of wireless telegraphy. After a number of successful demonstrations in London, Salisbury plain, and across the Bristol Channel, Marconi formed the Wireless Telegraph and Signal Company Limited (later Marconi Telegraph Company Limited) in 1887. He managed his longest-range transmission yet in that year over a distance of 12 miles, and in 1899, he established wireless communication across the English Channel between England and France. In 1901, he attempted to prove that radio waves would be unaffected by the earth’s geodesic curvature. Retrieving his patent number 7777 for “tuned or syntonetic telegraphy,” Marconi sent the first wireless signal across the Atlantic Ocean—2,100 miles between Poldhu, Cornwall, and St. John’s, Newfoundland, Canada.

Between 1902 and 1912, Marconi would patent other inventions mostly relating to his work on radio waves. Among them were a magnetic detector that would become the standard wireless receiver for years, the horizontal directional aerial antenna, and a “timed spark” system for generating continuous electromagnetic waves. He won the 1909 Nobel Prize for his work in wireless transmission. In 1932, after his 1920 discovery of short-wave radio (1.6 to 30 MHz wavelength), the world’s first radiotelephone link was established in Vatican City with the pope’s summer residence at Castel Gandolfo. After his death in 1879, Marconi was remembered as the father of modern communication technology.

Alexander Graham Bell’s patent for the telephone was filed in 1876, but it was not until J. A. Fleming’s patent of the diode in 1904 and Lee de Forest’s triode amplifier that wireless radiotelephony became possible. The year 1907 saw the rise of the commercial transatlantic wireless service, whose use of massive ground stations marked the end of cable-based telegraphy. In 1915, the first transmission of human voice reached San Francisco from New York, followed five years later by the first commercial broadcast. Before the onset of World War II, which would see a massive climb in wartime telecommunications research, the British Broadcasting Corporation began experiments in the technology known today as “television” in 1930. In 1958, the first telecommunications satellite, Project SCORE (Signal Communications by Orbiting Relay Equipment), was launched by an American Atlas rocket. Wireless communications reached a new revolution in 1969 with experiments in creating multinode computer networks with no centralized mainframe. The first was a four-node network connecting computers at four American universities that became known as ARPANET. This became the precursor to the modern-day Internet, which at its inception used old telephone and television wireless networks.

Wireless communication is known for its many advantages, both traditional and modern, that guided its selection as the dominant communications medium. It can convey information quickly and near instantaneously, reduce necessary hardware, reach remote areas, and address urgent situations using mobile devices. It is also more cost-effective. It is also vulnerable in

ways that were unknown in old cabled systems: the nature of wireless signals broadcasting in a medium makes them vulnerable to remote intrusion from eavesdropping and hacking, though this can be prevented by wireless intrusion prevention technology.

There are various forms of wireless communication suited for varying ranges and functions. Infrared signals use infrared (IR) radiation: electromagnetic waves at wavelengths above visible light and below microwaves. They are short-to-medium-range signals used primarily for communications and security control, as they require unobstructed line of sight between the photo light-emitting diode (LED) transmitter and photodiode receiver. Broadcast radio is the most common form of wireless communication and dispatches audio signals through the atmosphere as radio waves (electromagnetic waves between 300 GHz and 3 kHz in frequency). These can operate on frequency modulation (FM), encoding the audio information on varying frequencies, or amplitude modulation (AM), encoding the wave’s amplitude on a constant frequency. Microwave radio involves super-high-frequency (1 to 30 GHz) radio waves, almost always between ground stations and satellite communications systems. They require line of sight and operate two frequencies on single antennas but are vulnerable to adverse weather conditions. Satellite communications are simply space-based radio, uplinked to and from ground-based stations to onboard transponders. A single transponder can process 155 million bits per second, and a single satellite carries 24 to 72. Other forms of wireless communication are rare and almost exclusively short-range, line of sight signals: ultrasonic technology operates by sound higher than human hearing (22.1 kHz), electromagnetic induction transmits voltage through changing magnetic fields and is used in radio-frequency identification (RFID) technology, and free-space optical uses visible light in the atmosphere or space.

Wireless communications reached their modern culmination with the Internet, which still uses radio frequencies (2.4 to 5 GHz). With the advent of wireless routers, it is now possible for anyone to access this massive computer network for almost any location where radio waves can travel freely. It has provided the opportunity to connect other forms of hardware to

remote control (i.e., car ignitions, household heaters, lights, etc.) in an “Internet of things” using the same wireless frequencies used to communicate. This has also opened the door to new threats, as Internet accessibility enables intrusion by malicious parties, heralding a new revolution of “cyberwarfare.”

Andres Elvira

See also iPod; *Vol. 2, Sec. 1:* Bell, Alexander Graham; *Vol. 2, Sec. 2:* Radio; Triode Tube; *Vol. 2, Sec. 3:* Radar; SONAR; *Vol. 3, Sec. 1:* ARPANET; *Vol. 3, Sec. 2:* Internet; Microchip; Mobile Phone

Further Reading

- Garratt, G. R. M. 1994. *The History of the Radio from Faraday to Marconi*. London: Institution of Engineering and Technology.
- Goldsmith, Andres. 2005. *Wireless Communication*. Cambridge: Cambridge University Press.
- Trowbridge, Calvin D., Jr. 2009. *Marconi: Father of Wireless, Grandfather of the Radio, Great-Grandfather of the Cellphone: The Story of the Race to Control Long-Distance Wireless*. Charleston, SC: BookSurge.

YouTube

YouTube is an international video-sharing domain established in San Bruno, California, in February of 2005. The site was created by Chad Hurley, Jawed Karim, and Steve Chen, three former PayPal workers.

The site is a format that allows anyone in the world to upload videos as well as to share, rate, and comment on others' videos. People can upload documentaries, news, self-made media, previews, and/or video clips of movies and shows, and so on. YouTube created a forum for artists in the music industry to upload their content for profit through channels such as Vevo. Users are allowed to view videos when unregistered, but they may contribute their own videos when they register via e-mail or create an account.

However, not all types of videos are allowed to be uploaded. The video must be deemed appropriate for all ages. If a certain video is considered inappropriate for those under the age of 18, it is blocked for the normal public to view and can only be accessed if a user logs in to confirm his or her age. Videos that viewers consider inappropriate can be “flagged,” or rated as a threat. Google purchased the domain in November 2006. YouTube also offers special videos that require purchase among its sea of free videos. This service is called YouTube Red.

Rubayia D. Manju

See also Amazon.com; Facebook; Google; *Vol. 3, Sec. 1:* Silicon Valley; *Vol. 3, Sec. 2:* Apple; Jobs, Steve; Microsoft

Further Reading

- Botello, Chris. 2007. *YouTube for Dummies*. Hoboken, NJ: John Wiley & Sons.
- Ciampa, Rob. 2015. *YouTube Channels for Dummies*. Hoboken, NJ: John Wiley & Sons.

Bibliography: The Cold War to the Present

Section 1: The Cold War (1946–1979)

- Ackmann, Martha. 2004. *The Mercury 13: The True Story of Thirteen Women and the Dream of Space Flight*. New York: Random House.
- Beattie, Donald A. 2001. *Taking Science to the Moon: Lunar Experiments and the Apollo Program*. Baltimore: Johns Hopkins University Press.
- Benson, Michael. 2003. *Beyond Visions of the Interplanetary Probes*. New York: H. N. Abrams.
- Bolin, Bert. 2008. *A History of the Science and Politics of Climate Change: The Role of the Intergovernmental Panel on Climate Change*. New York: Cambridge University Press.
- Bonanos, C. 2012. *Instant: The Story of Polaroids*. New York: Princeton Architectural Press.
- Bureau, Caroline. 2007. *Answering 911: Life in the Hot Seat*. Wadena, MN: Borealis Books.
- Carson, Rachel. 1962. *Silent Spring*. Boston: Houghton Mifflin.
- Champlin, Charles. 1997. *George Lucas: The Creative Impulse: Lucasfilm's First Twenty-five Years*. New York: Harry N. Abrams.
- Cobb, Jerrie, and Jane Rieker. 2012. *Woman into Space: The Jerrie Cobb Story*. n.p.: Literary Licensing.
- Comfort, Nathaniel C. 2001. *The Tangled Field: Barbara McClintock's Search for the Patterns of Genetic Control*. Cambridge, MA: Harvard University Press.
- Conway, Erik M. 2015. *Exploration and Engineering: The Jet Propulsion Laboratory and the Quest for Mars*. Baltimore: Johns Hopkins University Press.
- Dessler, Andrew Emory, and Edward Parson. 2006. *The Science and Politics of Global Climate Change: A Guide to the Debate*. Cambridge: Cambridge University Press.
- Gilbert, Geoffrey. 2008. *Rich and Poor in America: A Reference Handbook*. Santa Barbara, CA: ABC-CLIO.
- Hargittai, M. 2015. *Women Scientists: Reflections, Challenges, and Breaking Boundaries*. New York: Oxford University Press.
- Harwood, William, and Stephen P. Maran. 2001. *Space Odyssey: Voyaging Through the Cosmos*. Washington, D.C.: National Geographic.
- Holt, Nathalia. 2016. *Rise of the Rocket Girls: The Women Who Propelled Us, from Missiles to the Moon to Mars*. New York: Little, Brown.
- Hyde, Charles K. 2013. *Arsenal of Democracy: The American Automobile Industry in World War II*. Detroit: Wayne State University Press.
- Jones, H. W. 2014. *In Vitro Fertilization Comes to America: Memoir of a Medical Breakthrough*. Williamsburg, VA: Jamestowne Bookworks.
- Kaplan, Eliot, and Christopher J. Hegarty. 2017. *Understanding GPS/GNSS: Principles and Application*. Boston: Artech House.
- Kenschaft, Patricia Clark. 2005. *Change Is Possible: Stories of Women and Minorities in Mathematics*. Providence, RI: American Mathematical Society.
- Lear, Linda. 2009. *Rachel Carson: Witness for Nature*. Boston: Houghton Mifflin Harcourt.
- Luque, R, and J. A. Melero, eds. 2012. *Advances in Biodiesel Production: Processes and Technologies*. Woodhead Publishing Series in Energy. Cambridge: Woodhead.
- Marcel, Kurt, ed. 2015. *Biodiesel: Advanced Approaches and Applications*. New York: Clanrye International.
- May, Elaine Tyler. 2010. *America and the Pill: A History of Promise, Peril, and Liberation*. New York: Basic Books.

- McCartney, Scott. 1999. *ENIAC: The Triumphs and Tragedies of the World's First Computer*. New York: Walker.
- McGrayne, Sharon Bertsch. 2001. *Nobel Prize Women in Science: Their Lives, Struggles, and Momentous Discoveries*. Washington, D.C.: Joseph Henry Press.
- Milner, Greg. 2016. *PinPoint: How GPS Is Changing Technology, Culture, and Our Minds*. New York: W. W. Norton.
- Oshinsky, David M. 2006. *Polio: An American Story*. Oxford: Oxford University Press.
- Reagan, Ancel. 2017. *What's Your Emergency?* St. Paul: Minnesota Historical Society Press.
- Riegel, Ronald J. 2017. *Laser Therapy in Veterinary Medicine: Photobiomodulation*. New York: John Wiley & Sons.
- Rogers, Ben. 2007. *Nanotechnology: Understanding Small Systems*. New York: CRC Press.
- Shetterly, Margot Lee. 2016. *Hidden Figures*. New York: HarperCollins.
- Slegman, Anthony E. 1986. *Lasers*. Palo Alto, CA: Miller Scheier Associates.
- Sway, Rachel. 2017. *Trailblazers: 33 Women in Science Who Changed the World*. n.p.: Follettbound.
- Taylor, Nick. 2000. *Laser: The Inventor, The Nobel Laureate, and The Thirty-Year Patent War*. New York: Simon & Schuster.
- Tone, Andrea. 2001. *Devices & Desires: A History of Contraceptives in America*. New York: Hill and Wang.
- Vendel, Curt, and Marty Goldberg. 2012. *Atari Inc.: Business is Fun*. New York: Syzygy Press.
- Westbrook, M. 2001. *The Electric Car: Development and Future of Battery, Hybrid and Fuel-cell Cars*. London: Institution of Electrical Engineers.
- Bell, Michael F. 2012. *The Invisible Crime: Illegal Microchip Implants and Microwave Technology*. New York: Brighton.
- Bradley, D. 2011. "A Personal History of the IBM PC." *Computer* 44, no. 8: 19–25.
- Bride, E. 2011. "The IBM Personal Computer: A Software-Driven Market." *Computer* 44, no. 8: 34–39.
- Brock, David C. 2010. *Makers of the Microchip: A Documentary History of Fairchild Semi-Conductor*. Boston: MIT Press.
- Duggins, Pat. 2009. *Final Countdown: NASA and the End of the Space Shuttle Program*. Gainesville: University Press of Florida.
- Ferguson, Charles D. 2001. *Nuclear Energy: What Everyone Needs to Know*. New York: Oxford University Press.
- France, David. 2016. *How to Survive a Plague: The Inside Story of How Citizens and Science Tamed AIDS*. New York: Knopf.
- Gates, Bill. 1999. *Business @ The Speed of Thought: Using a Digital Nervous System*. New York: Warner Books.
- Gordon, R. Michael. 2008. *The Space Shuttle Program: How NASA Lost Its Way*. Jefferson, NC: McFarland.
- Hillston, Kevin. 2005. *The Internet Revolution*. n.p.: Omnigraphics.
- Hitt, David, and Heather R. Smith. 2014. *Bold They Rise: The Space Shuttle Early Years, 1972–1986*. Lincoln: University of Nebraska Press.
- Isaacson, Walter. 2014. *The Innovators: How a Group of Hackers, Geniuses, and Geeks Created the Digital Revolution*. New York: Simon & Schuster.
- Marck, Bernard. 2013. *Women Aviators: From Amelia Earhart to Sally Ride, Making History in Air and Space*. New York: Flammarion.
- McDonald, Allan J., and James R. Hansen. 2009. *Truth, Lies, and O-Rings: Inside the Space Shuttle Challenger Disaster*. Gainesville: University Press of Florida.
- McKellar, Shelley. 2017. *Artificial Hearts: The Allure and Ambivalence of Controversial Medical Technology*. Baltimore: Johns Hopkins University Press.
- Montgomery, Sy. 2009. *Walking with the Great Apes*. New York: Chelsea Green.

Section 2: The Post–Cold War Era (1980–1999)

- Bainbridge, David A, and Kenneth L Haggard. 2011. *Passive Solar Architecture: Heating, Cooling, Ventilation, Daylighting, and More Using Natural Flows*. White River Junction, VT: Chelsea Green.
- Behling, Sophia, Sophia Behling, Bruno Schindler, and Stefan Behling. 2000. *Solar Power: The Evolution of Sustainable Architecture*. New York: Prestel.

- Murray, Charles J. 1998. *The Supermen: The Story of Seymour Cray and the Technical Wizards Behind the Supercomputer*. New York: John Wiley & Sons.
- National Academy of Engineering. 2003. *Completing the "Big Dig": Managing the Final Stages of Boston's Central Artery/Tunnel Project*. Washington, D.C.: National Academy Press.
- Sachs, Carolyn, et al. 2016. *The Rise of Women Farmers and Sustainable Agriculture*. Iowa City: University of Iowa Press.
- Sherr, Lynn. 2014. *Sally Ride: America's First Woman in Space*. New York: Simon & Schuster.
- Thistlewaite, Rebecca. 2013. *Farms with a Future: Creating and Growing a Sustainable Farm Business*. New York: Chelsea Green.
- Thomas, Randall, and Amory Lovins. 2001. *Photovoltaics and Architecture*. London: Spon Press.
- Tiwari, G. N. 2002. *Solar Energy: Fundamentals, Design, Modelling and Applications*. Boca Raton, FL: CRC Press.
- Weil, David, ed. 2002. *Leaders of the Information Age*. New York: H. W. Wilson.
- Section 3: The New Millennium (2000–Present)**
- Beahm, George. 2012. *The Boy Billionaire: Mark Zuckerberg in His Own Words*. n.p.: Agate B2.
- Catchpole, John E. 2008. *The International Space Station: Building for the Future*. Berlin: Springer.
- Choudhry, Hani, and Wei Wu. 2013. *Next Generation Sequencing in Cancer Research: Volume 1: Decoding the Cancer Genome*. New York: Springer New York.
- deGrasse Tyson, Neil. 2004. *The Sky Is Not the Limit: Adventures of an Urban Astrophysicist*. New York: Prometheus Books.
- deGrasse Tyson, Neil. 2017. *Astrophysics for People in a Hurry*. New York: W. W. Norton.
- Forshaw, Jeff, and Brian Cox. 2011. *The Quantum Universe*. New York: Da Capo Press.
- Good, K. 2013. "From Scrapbook to Facebook: A History of Personal Media Assemblage and Archives." *New Media & Society* 15, no. 4: 557–73.
- Grandin, Temple, and Richard Panek. 2013. *The Autistic Brain: How Different Kinds of Minds Succeed*. New York: Houghton Mifflin.
- Greaves, Mel, and Carlo C. Maley. 2016. *Frontiers in Cancer Research: Evolutionary Foundations, Revolutionary Directions*. New York: Springer New York.
- Hawking, Stephen. 2017. *A Brief History of Time*. New York: Bantam.
- Hawking, Stephen, and Simon Prebble. 2001. *The Universe in a Nutshell*. New York: Random House.
- Henneberg, Susan. 2017. *Virtual Reality*. New York: Greenhaven.
- Jamison, David E., ed. 2010. *The International Space Station*. New York: Nova Science.
- Jemison, Mae. 2001. *Find Where the Wind Goes: Moments from My Life*. New York: Scholastic.
- Kirkpatrick, David. 2011. *The Facebook Effect: The Inside Story of the Company That Is Connecting the World*. New York: Simon & Schuster.
- Lakdawalla, Emily. 2018. *The Design and Engineering of Curiosity: How the Mars Rover Performs Its Job*. New York: Springer Praxis Books.
- Lorenz, Ralph, and Jacqueline Mitton. 2002. *Lifting Titan's Veil: Exploring the Giant Moon of Saturn*. Cambridge: Cambridge University Press.
- Lurquin, Paul. 2002. *High Tech Harvest: Understanding Genetically Modified Food Plants*. New York: Westview Press.
- Manning, Rob, and William Simon. 2014. *Mars Rover Curiosity: An Inside Account from Curiosity's Chief Engineer*. Washington, D.C.: Smithsonian Books.
- McElheny, Victor K. 2012. *Drawing the Map of Life: Inside the Human Genome Project*. New York: Basic Books.
- Meltzer, Michael. 2015. *The Cassini-Huygens Visit to Saturn: An Historic Mission to the Ringed Planet*. New York: Springer Praxis Books.
- Shaw, Ian G. R. 2014. *The Rise of the Predator Empire: Tracing the History of U.S. Drones*. Minneapolis: University of Minnesota Press.
- Susskind, Leonard, and Art Friedman. 2014. *Quantum Mechanics*. New York: Basic Books.
- Walker, Michael S. 2017. *Quantum Fuzz*. New York: Prometheus Books.
- Wapner, Jessica. 2014. *The Philadelphia Chromosome: A Genetic Mystery, a Lethal Cancer, and the Improbable Invention of a Lifesaving Treatment*. New York: Workman.

- Weasel, Lisa. 2009. *Food Fray: Inside the Controversy over Genetically Modification*. New York: AMACON.
- Weschler, Toni. 2015. *Taking Charge of Your Fertility, 20th Anniversary Edition: The Definitive Guide to Natural Birth Control, Pregnancy Achievement, and Reproductive Health*. New York: William Morrow Paperbacks.
- White, Michael, and John Gribbin. 2016. *Stephen Hawking: A Life in Science*. New York; London: Pegasus.
- Zeigler, Mary. 2015. *After Roe: The Lost History of the Abortion Debate*. Cambridge, MA: Harvard University Press.

Editors and Contributors

Editors

Peg A. Lamphier, PhD, teaches interdisciplinary humanities at California State Polytechnic University and American History at Mount San Antonio College. Lamphier wrote *Kate Chase and William Sprague: Politics and Gender in a Civil War Marriage* (Nebraska University Press, 2003), *Spur Up Your Pegasus: Family Letters of Salmon, Kate and Nettie Chase, 1844–1873* (Kent State University Press, 2009), and *Women in American History: A Social, Political, and Cultural Encyclopedia* (ABC-CLIO, 2016). She also writes novels set in the Civil War, including *The Lincoln Special* (2017), *The Great Show* (2017), and *The Bold Life of Louis Palma di Cesnola* (2018), as well as a gaslamp fantasy novel, *Violent Delights and Vampires*. She lives in the mountains of Southern California with seven tortoises, five dogs, and one husband.

Rosanne Welch, PhD, teaches humanities courses for California State Polytechnic University, Pomona, and screenwriting history for the Stephens College MFA in Screenwriting. A film and television historian, Welch wrote *The Encyclopedia of Women in Aviation and Space* (ABC-CLIO, 1998), *Why The Monkees Matter: Teenagers, Television and American Pop Culture* (McFarland, 2016), coedited *Women in American History: A Social, Political, and Cultural Encyclopedia* (ABC-CLIO, 2016), and published the chapter “Hidden Behind Hoopskirts: The Many Women of Hollywood’s Civil War Sagas” in *The American Civil War on Film and TV: Blue and Gray in Black and White and Color* (Lexington Books, 2018).

Contributors

Arno Aghababian
Independent Scholar
Los Angeles, California

Adolfo Alarcon
Independent Scholar
Los Angeles, California

Mubarak Alhassen
Independent Scholar
West Covina, California

Rachel Alzaga
Independent Scholar
Pomona, California

Christian Amaya
Independent Scholar
Pomona, California

Victor Anguiano
Independent Scholar
Bell, California

Ellen M. Anstey
Tsongas Industrial History Center
Lowell, Massachusetts

Daniel Aparicio
Independent Scholar
Pomona, California

Carina J. Ariss

Independent Scholar
Pomona, California

Joshua Austria

Independent Scholar
Alta Dena, California

Jose D. Avelar

Independent Scholar
Baldwin Park, California

Rolando Avila

University of Texas, Rio Grande Valley

William E. Balsells

Independent Scholar
Pomona, California

Maricela F. Baltazar

Independent Scholar
Pomona, California

Kathleen Barker

Massachusetts Historical Society
Boston, Massachusetts

D. L. Barnum

Independent Scholar
Pomona, California

Jenna Barrett

Independent Scholar
Hermosa Beach, California

Stephanie M. Bayless

Butler Center for Arkansas Studies
Little Rock, Arkansas

Nancy Beach

University of North Carolina
Chapel Hill, North Carolina

Anthony Bekdas

Independent Scholar
Pomona, California

Roshunda L. Belton

Grambling State University
Grambling, Louisiana

Brenna Biggs

University of California, Irvine
Irvine, California

Brian C. Black

Penn State Altoona
Altoona, Pennsylvania

Katrina Boggus

Independent Scholar
Alta Loma, California

Leslie Botello

Independent Scholar
Los Angeles, California

Mark D. Bowles

American Public University, Ohio

Taylor Alexandra Boyett

Independent Scholar
Pomona, California

Wendy Braun

University of Tennessee
Knoxville, Tennessee

Kyle Bridge

University of Florida
Gainesville, Florida

Linda Briley-Webb

Independent Scholar
Scottsdale, Arizona

Emma E. L. Burke

Montana State University
Bozeman, Montana

Claudio Buttice

University of Palermo
Palermo, Italy

Bryan Cabrera

Independent Scholar
Pomona, California

William Michael Camp

Emory University
Atlanta, Georgia

Belen Cardenas

Independent Scholar
Whittier, California

Serena Castillo

Independent Scholar
Alta Loma, California

Alden Gabriel Reyes Caterio

Independent Scholar
Rosemead, California

Warod Changpradith

Independent Scholar
Pomona, California

D. Chatman-Riley

California State Polytechnic
Pomona, California

Chi Lao

Independent Scholar
Pomona, California

Marilyn Chin

LaGuardia Community College
New York, New York

Jordan Ciccarelli

Independent Scholar
Pomona, California

Christian Cobo

Independent Scholar
San Dimas, California

Evann W. Conditt

Independent Scholar
Pomona, California

Goo Conejos

Independent Scholar
Pomona, California

Nathaniel C. Cooley

Independent Scholar
Upland, California

Wynton Cooley

Independent Scholar
Pomona, California

Josue Cortez

Independent Scholar
Los Angeles, California

Walter Cummins

Fairleigh Dickinson University
Teaneck, New Jersey

Christopher Cumo

Independent Scholar
Massillon, Ohio

Nicole Curtis-Brown

Independent Scholar
Martinez, California

Sara L. Darella

Independent Scholar
Pomona, California

Deborah L. Daughetee

Independent Scholar
Las Vegas, Nevada

Lusine Davtyan

Independent Scholar
Pomona, California

Keri Dearborn

Independent Scholar
Woodland Hills, California

Eileen Diaz

Independent Scholar
Pomona, California

Carol E. Dietrich

Independent Scholar
Pomona, California

Joshua Drewry

Independent Scholar
Pomona, California

John A. Drobnicki

York College, City University of New York
New York, New York

Amanda Elaine Duran

Independent Scholar
Los Angeles, California

Meredith Eliassen

San Francisco University
San Francisco, California

Andres Elvira

Loyola Marymount University
Los Angeles, California

James L. Erwin

Independent Scholar
Des Moines, Iowa

Jonathan A. Escobar

Independent Scholar
Pomona, California

Alejandro Esparza

Independent Scholar
Pomona, California

Shacovik Flores

Independent Scholar
Beaumont, California

Michael R. Fluhrer

Independent Scholar
Pomona, California

Amy Helene Forss

Metropolitan Community College
Omaha, Nebraska

John A. Francisco

Independent Scholar
Pomona, California

Alicia L. Garcia

Independent Scholar
Los Angeles, California

Claudia Garcia

Independent Scholar
Pomona, California

Karen S. Garvin

Independent Scholar
College Park, Maryland

Michelle Gatewood

Independent Scholar
Pomona, California

Julian Gliniecki

Independent Scholar
Pomona, California

M. Carmen Gomez-Galisteo

Universidad Francisco de Vitoria
Madrid, Spain

Sebastian Gottwald

Independent Scholar
Pomona, California

Zachary Green

Independent Scholar
Pomona, California

Sean Groves

Independent Scholar
Pomona, California

Marissa A. Guerrero

Independent Scholar
West Covina, California

Kristine Ashton Gunnell

UCLA Center for the Study of Women
Los Angeles, California

Jarice Hanson

University of Massachusetts
Amherst, Massachusetts

Adrienne Harwell

Addis Ababa, Ethiopia

Nancy Hendricks

Arkansas State University
Jonesboro, Arkansas

Jatziri Hernandez

Independent Scholar
Pomona, California

Rianna Hernandez-Thorn

Independent Scholar
Pomona, California

Jonathan G. Herrera

Independent Scholar
Pomona, California

Wences Jose

Independent Scholar
Pomona, California

Mark S. Joy

University of Jamestown
Jamestown, North Dakota

Jordan Joya

Independent Scholar
Monrovia, California

Patrick Ketterer

Independent Scholar
Diamond Bar, California

Dylan Keys

Independent Scholar
Pomona, California

Chelsea Kirkpatrick

Independent Scholar
Los Angeles, California

Mei B. Klein

California State Polytechnic
Pomona, California

Jeremy C. Kleve

Independent Scholar
Pomona, California

Sjoen Koepke

Independent Scholar
Pomona, California

Rebecca Kohn

San Jose State University
San Jose, California

Daichi Kojima

Independent Scholar
Pomona, California

Allen Kuo

Independent Scholar
Diamond Bar, California

Tom Conrad Landry

Independent Scholar
Orange, California

Joanne Lee

Independent Scholar
San Francisco, California

Rachel Levy

Harvey Mudd College
Claremont, California

Tracy Liu

Independent Scholar
Pomona, California

Alan Lopez

Independent Scholar
Pomona, California

Andres Lopez

Independent Scholar
Los Angeles, California

Melissa Lopez Gutierrez
Independent Scholar
Pomona, California

Amy Lou
Independent Scholar
Pomona, California

Eric G. Lovik
Independent Scholar
Pomona, California

Brian Lugo
Independent Scholar
Pomona, California

Christopher Jay Lujan
Independent Scholar
Pomona, California

Mariana Magaña
Independent Scholar
Porterville, California

Peter Magistrale
Independent Scholar
Pomona, California

Rubayia D. Manju
Independent Scholar
Pomona, California

Michael David Martinez
Independent Scholar
Pomona, California

Justin Matela
Independent Scholar
Los Angeles, California

Charles McCrary
Independent Scholar
Los Angeles, California

Joshua McPhail
Independent Scholar
Pomona, California

Chelsea Medlock
Independent Scholar
Pomona, California

Ryan M. Melendez
Independent Scholar
Los Angeles, California

Fredy G. Mena
Independent Scholar
Pomona, California

Camille Michaluk
Independent Scholar
Los Angeles, California

Alberta M. Miranda
California State Polytechnic
Pomona, California

Patit Paban Mishra
Sambalpur University
Sambalpur, India

Karl Terrence D. Molina
Independent Scholar
Pomona, California

Raul Monzon
Independent Scholar
Pomona, California

John A. Morello
DeVry University
Addison, Illinois

Rebecca Morello
Independent Scholar
Addison, Illinois

Hiba Mouri
Independent Scholar
Pomona, California

Eric D. Muro
Independent Scholar
Pomona, California

Richard Matthew Musquiz
Independent Scholar
Los Angeles, California

Marissa N. Nahay
Independent Scholar
Los Angeles, California

Thomas A. Newton
Independent Scholar
Pomona, California

Jennifer Kyoko Nguyen
Independent Scholar
Los Angeles, California

Kim Nguyen
Independent Scholar
Pomona, California

Sydney Nguyen
Independent Scholar
Pomona, California

Martha Njuguna
Independent Scholar
Moreno Valley, California

Lydia Nolte
Independent Scholar
Pomona, California

Kristin O’Brassill-Kulfan
University of Leicester
Leicester, United Kingdom

Cassady O’Reilly-Hahn
Independent Scholar
Claremont, California

Monica Orozco
Independent Scholar
Pomona, California

Lorrie Mae Panis
Independent Scholar
Pomona, California

Cynthia J. Parker
Independent Scholar
Northridge, California

Bhavesh Mukeshkumar Patel
Independent Scholar
Pomona, California

Eduardo Paz
Independent Scholar
Pomona, California

Omar Pelcastre
Independent Scholar
Pomona, California

Alan S. Peña
Independent Scholar
Pomona, California

Madison Pena
Independent Scholar
Pomona, California

Ilia D. Petrosan
Independent Scholar
Pomona, California

Randy Pham
Independent Scholar
Pomona, California

Kathleen Phan
Independent Scholar
Pomona, California

Olivia Phan
Independent Scholar
Pomona, California

Sean P. Phillips
Independent Scholar
Pomona, California

Wai L. Phyo
Independent Scholar
Shanghai, China

Laura J. Ping

The Graduate Center, City University of New York
New York, New York

Katarina M. Ponomaroff

Independent Scholar
Pomona, California

Sohel Poojani

Independent Scholar
Pomona, California

Elliott Popel

Independent Scholar
Pomona, California

Robin Potter

Brooklyn College
Brooklyn, New York

William H. Pruden III

Ravenscroft School
Raleigh, North Carolina

George P. Quan

Independent Scholar
Pomona, California

Nicole Quintero

Independent Scholar
Pomona, California

Hannah Reutershan

Independent Scholar
Pomona, California

Tiffany Rhoades

Independent Scholar
New York, New York

Damian Rodgers

Independent Scholar
Pomona, California

Abhijit Roy

Independent Scholar
Pomona, California

Mousumi Roy

Independent Scholar
Pomona, California

Scott Russell

Independent Scholar
Erie, Pennsylvania

Frank Salamone

Iona College
New Rochelle, New York

Jesus Salas

Independent Scholar
Pomona, California

Greg Salcido

Independent Scholar
Pomona, California

Moriah Saldana

Independent Scholar
San Diego, California

Michael Sandoval

Independent Scholar
Pomona, California

Jazmin Sandoval Castillo

Independent Scholar
Pomona, California

Jessica Schmidt

Independent Scholar
Pomona, California

Kathleen Simonton

Edmonds Community College
Lynnwood, Washington

Elijah Sisson

Independent Scholar
Pomona, California

Quentin R. Skrabec

University of Findlay
Findlay, Ohio

Kalan Small

Independent Scholar
Pomona, California

Lee Smith

Independent Scholar
Baton Rouge, Louisiana

Pamela Solis

Independent Scholar
Pomona, California

Kyle Soren

Independent Scholar
Riverside, California

Terry Steagall

Independent Scholar
San Dimas, California

Cody J. Swanson

Independent Scholar
Pomona, California

Koyo Takahashi

Independent Scholar
Pomona, California

Lynda C. Titterington

Independent Scholar
Columbus, Ohio

Johnson D. Ton

Independent Scholar
Pomona, California

Therese Torres

California State University
Fullerton, California

Dan Tran

Independent Scholar
Pomona, California

Shinha Tsuchida

Independent Scholar
Pomona, California

Elijah Turner

Independent Scholar
Pomona, California

Stefka Tzanova

York College
Jamaica, New York

Dannela Azul Valencia

Independent Scholar
Indio, California

Enrique Garcia Villa

Independent Scholar
Pomona, California

Bryan Villafuerte

Independent Scholar
Pomona, California

Alexandria Beatrice E. Vinuya

Independent Scholar
Pomona, California

Jacky Voong

Independent Scholar
Rosemead, California

Alex Vu

Independent Scholar
Pomona, California

Linda S. Watts

University of Washington
Bothell, Washington

Timothy J. Watts

Kansas State University
Manhattan, Kansas

Tiffany K. Wayne

Independent Scholar
Santa Cruz, California

Sarah Mae Halpern Weise

Independent Scholar
Valley Village, California

Reed K. Wilkinson

Independent Scholar
Yucaipa, California

James A. Wren

San Jose State University
San Jose, California

Xuanlin Xu

Independent Scholar
Pomona, California

Lenny Yang

Independent Scholar
Valencia, California

Jacob W. Young

Independent Scholar
Pomona, California

Brian Yu

Independent Scholar
Newport Beach, California

Michael Yu

Independent Scholar
Pomona, California

Cynthia M. Zavala

Independent Scholar
La Puente, California

Index

Boldface numbers refer to volume numbers.

- Abbe, Cleveland (1838–1916), **2**:7–9
 Monthly Weather Review founded by, **2**:8
 National Geographic Society cofounder, **2**:8
- Abbott, John G., **1**:210–211
- Abbott Laboratories, **1**:179
- AC generator and transformer, **2**:9–10
 at Chicago World’s Columbian Exposition, **2**:58, 63, 107
 Great Barrington Electrification, **2**:9, 62
 primary document: AIEE biography for William Stanley (1934), **2**:10
 and “war of the currents,” **2**:9, 58, 62–63
- AC induction motor, **2**:10–11, 148
 primary document: Tesla’s patent (1896), **2**:11–14
- Acetylsalicylic acid. *See* Aspirin
- Acquired immune deficiency syndrome (AIDS). *See* AIDS research
- Adams, Ansel, **2**:293; **3**:80
- Adams, John, **1**:8, 10, 144, 260
- Adams, Thomas, **2**:157, 210
- Addams, Jane, **2**:172
- Adding machine with keys, **2**:14, 114
- Adding machines, **2**:14, 113–114
 Arithmometer, **2**:113–114
 automatic calculation, **1**:113–114
 clearing lever (“machine gun of the office”), **2**:114
 Comptometer, **2**:113–114
 Dalton Adding Machine (10 numerical buttons), **2**:114
 and industrialization of leisure, **2**:5
 and paper copies of tabulations, **1**:114
 See also Calculators
- Additive manufacturing. *See* 3-D printing
- Adhesive bandages, **2**:185. *See also* Band-Aid
- Adhesive tape, **1**:174–175
 Band-Aid, **1**:175; **2**:175, 185
 duct tape, **1**:175; **2**:256
 masking tape, **1**:175; **2**:113, 218, 241
 Scotch Tape (cellophane tape), **2**:113, 218, 241, 253
 as staple in American homes, **2**:253
 uses for, **1**:175
- Advanced Research Projects Agency Network. *See* ARPANET
- Aerosol spray can, **2**:176
- Aerosols
 and carbon capture and storage (CCS), **3**:40
 and chlorofluorocarbons (CFCs), **2**:176; **3**:38
 and Clean Air Act (1977), **2**:176
 definition of, **2**:176
 and Freon, **2**:205
- Agassiz, Elizabeth Cabot Cary, **1**:176, 259
 American Philosophical Society member, **1**:9
 Louis Agassiz: His Life and Correspondence, **1**:176–177
- Agassiz, Louis (1807–1873), **1**:46, 175–176
 primary document: excerpt from journal (1846), **1**:176–177
- Age of Reason. *See* Enlightenment
- Agent Orange, **3**:9–10
 discontinuation of use of, **3**:7
 naming of, **3**:9
 Operation Pacer IVY (removal of barrels from Vietnam), **3**:10
 producers of, **2**:50; **3**:9
 protests against, **3**:7
 toxicity and health effects of, **3**:9–10
- AI. *See* Artificial intelligence (AI)
- AIDS research, **3**:171–173
 AZT (zidovudine, drug treatment), **3**:172, 197
 discovery of HIV, **3**:172
 Doha declaration, **3**:172
 ELISA blood test, **3**:172
 first verified HIV case, **3**:171
 highly active antiretroviral therapy (HAART), **3**:172
 history of HIV/AIDS, **3**:171
 HIV mutations, **3**:173
 and Kaposi’s sarcoma, **3**:171, 173
 and medical technology, **3**:249
 and National Institutes of Health, **2**:105; **3**:173, 175
 and pneumocystis carinii pneumonia (PCP), **3**:171, 173
 prevention of HIV transmission, **3**:172
 primary document: introduction to AIDS archive by C. Everett Koop, **3**:173–177
 rapid HIV tests, **3**:172, 249
 and research by Salk, Jonas, **3**:126
 saquinavir (drug treatment), **3**:172

- “Air” athletic shoes, 3:11
- Airplane, 2:176–177
- airmail delivery, 2:255–256
 - contribution to decline in railroad ridership, 1:290–291
 - helicopter compared with, 2:276
 - history of, 2:176
 - and internal combustion engines, 1:120
 - and mass production, 1:75
 - first international flights (Pan American), 2:178
 - first powered, controlled aircraft (Wright brothers), 2:7, 164–166, 170–171, 178, 312
 - first transatlantic flight (Charles Lindbergh), 2:175
 - and military-industrial complex, 3:89, 90
 - NASA’s research benefits for, 3:95
 - and National Advisory Committee for Aeronautics (NACA), 2:223
 - and Pauling oxygen meter, 3:111
 - and stealth technology, 3:138–139
 - submerged airplane retrieval systems, 2:319
 - in Vietnam War, 3:9–10
 - and Whiton Centering Machine, 1:67
 - in World War I, 2:75, 171, 176, 178, 234; 3:48
 - in World War II, 2:189, 223, 234, 255–256, 261–262, 300, 301; 3:7
- See also* Drones
- Airplane deicer, 2:189; 3:254–255
- Alaska Highway, 2:257–260
- environmental effects of, 2:258–259
 - primary document: excerpt from Ruth Gruber’s study of highway routes to Alaska (1941), 2:259–260
- Alcott, Bronson, 1:168
- Alcott, Louisa May, 1:191, 306
- Alcott, William Andrus, 1:236
- Alexander, Edward Porter, 1:186
- Allen, Horatio, 1:181
- Allen, Paul, 3:199–200, 217
- Allestree, Richard, 1:11
- Almanacs. *See* Astronomical almanacs
- Almy, Brown, and Slater, 1:101, 147
- Almy, William, 1:101, 146–147
- Amalgamated Clothing Workers of America (ACWA), 2:14–16
- commitment to “new unionism,” 2:14
 - and formation of Congress of Industrial Organizations (CIO), 2:15
- See also* Labor and labor unions
- Amazon Web Services, 3:255–256, 258
- central hubs, 3:255
 - popular services, 3:255
 - users, 3:250, 255
- Amazon.com, 3:256–258
- acquisitions, 3:257, 266
 - Amazon Prime, 3:258
 - Kindle e-book reader, 3:251, 258, 265, 312
 - history of, 3:256–258
 - influence of, 3:247, 256
 - Linux’s influence on, 3:318
 - as tech start-up, 3:166, 301
 - video streaming, 3:323
- American Academy of Arts & Sciences, 1:73
- American Philosophical Society (APS), 1:8–10
- and Franklin, Benjamin, 1:4, 8–10, 45, 71–72
 - grants program, 1:9
 - and Jefferson, Thomas, 1:4, 8–9, 45, 158
 - Lewis and Clark Expedition sponsor, 1:124, 125
 - library and museum, 1:9–10
 - members, 1:8–9, 45, 46
 - and natural history movement, 1:78
 - origin and goals, 1:8, 45
 - primary document: APS’s favoring exploration of the Alaskan coast (1868), 1:10–11
 - publications program, 1:10, 97
 - sponsor of Lewis and Clark Expedition, 1:45, 124, 125
 - sponsor of Rittenhouse, David, 1:45
- American Telephone and Telegraph Company (AT&T), 2:16–17
- acquisitions of Time Warner and DirecTV, 2:17
 - AT&T Mexico, 2:17
 - Audion (triode) rights sold to, 2:196, 246
 - Bell Labs established by, 2:186, 324
 - Clarke, Edith, at, 2:268
 - court-ordered dismantling of, 2:17, 325
 - declared a monopoly by Department of Justice, 2:16, 17, 325
 - established by National Bell Telephone Company, 2:16, 27, 324
 - first long-distance lines of, 2:16
 - first undersea cable installed by, 2:16
 - Holmes Electric Protective Company purchased by, 1:183
 - innovations of, 2:16–17
 - and television technology, 2:17, 326
 - and Western Electric (subsidiary), 2:186
 - and Western Union, 1:311
 - and World War I, 2:16
 - and World War II, 2:17
- See also* Bell Telephone Laboratories
- Ames, Nathaniel, 1:11–12
- Amino acids, 3:5. *See also* DNA (deoxyribonucleic acid)
- Amphibious steam vehicle, 1:79–81
- Oruktor Amphibolos*, 1:79–81, 107, 118
 - primary document: image of amphibious steam vehicle (1834), 1:81
- Anderson, Herbert, 2:272
- Anderson, James, 1:302
- Anderson, Mary (1866–1953), 2:179
- Anderson, Paul Thomas, 3:135
- Anderson, Robert, 3:50

- Anesthesia, 1:178–179
 - chloroform, 1:179, 256
 - “ether frolics,” 1:178
 - nitrous oxide, 1:178, 202, 203, 246–247
 - sulfuric ether, 1:246–247
 - types of, 1:178; 247
- Antebellum Industrialization and the Civil War (1820–1865), 1:167–174
 - abolition movement, 1:171–172
 - agricultural innovation, 1:171–172
 - communication innovations, 1:169
 - early women’s rights movement, 1:170, 172
 - economic depression, 1:167, 171, 232
 - education, 1:169–170
 - financial panic of 1837, 1:167, 204, 217
 - impact of electronic telegraph, 1:167
 - industrial advancements, 1:168–169
 - institutional reform, 1:167
 - laissez-faire, free-market economics, 1:167, 171
 - Jacksonian democracy, 1:167
 - Patent Act of 1836, 1:170
 - population increases, 1:167
 - Second Great Awakening, 1:168, 235–236
 - Transcendental Movement, 1:168, 170, 171
- Antiballistic missiles (ABMs), 3:11–12
 - and Anti-Ballistic Missile Treaty (1972), 3:12, 239–240
 - Strategic Defense Initiative (SDI or “Star Wars”), 3:12, 90, 239–240
- Antibiotic, 3:13–14
 - antibiotic-resistant GM species, 3:271
 - and cattle, 2:145
 - chloramphenicol, 3:5
 - development of trimethoprim, 3:196
 - importance of, 3:5, 300–301, 306–307
 - nystatin, 3:5, 13–14
 - penicillin, 2:6, 256–257, 300–301, 306–307; 3:5, 13
 - and resistant bacteria, 2:306
- Antibiotic bandages, 2:185
- Apple, 3:177–179
 - Apple TV, 3:323
 - competition with IBM, 3:177
 - controversy and criticism, 3:178–179
 - educational marketing campaign, 3:177
 - Facebook App, 3:269
 - Google as Safari’s default search engine, 3:253
 - HyperCard, 3:190
 - iCloud, 3:178, 211
 - iMac, 3:178, 198
 - iPad, 3:178, 180, 153, 209, 211–212
 - iPhone, 3:178, 179, 180, 209, 219, 211–212, 219, 251, 269, 311–312
 - iPod, 3:121, 178, 180, 209, 211–212, 251, 286, 298–299, 311
 - iTunes, 3:178, 188, 209, 252, 286, 299, 308, 311
 - Lisa, 3:177
 - Macintosh, 3:165, 177–178, 209–210, 212, 213, 245
 - Microsoft programs for, 3:200
 - NeXT acquired by, 3:178
 - and open-source movement, 3:221–222
 - and portability, 3:253–254
 - Power Macintosh (Power Mac), 3:178
 - PowerBook, 3:178
 - Quick Take, 2:57; 3:194
 - ROKR, 3:311
 - Swift coding language, 3:222
 - and touch screen technology, 3:251
 - and Trinity of computers, 3:223
 - See also* Jobs, Steve; Wozniak, Steve
- Apple I, 3:177, 209–210, 244
- Apple II, 3:179–180
 - BASIC programming language, 3:179, 244
 - color monitor, 3:179, 223
 - competition with Commodore, 3:179, 224
 - competition with IBM, 3:205, 206
 - competition with Radio Shack, 3:179
 - cost, 3:180, 223
 - and Dell, Michael “Saul,” 3:192–193
 - mouse-central interfact, 3:159
 - open architecture system, 3:42, 180
 - success and importance of, 3:177, 180, 205, 209–210, 223, 244
 - user-friendliness, 3:179–180, 209–210, 223
 - and *VisiCalc*, 3:180, 206, 224
- Apple IIc, 3:165
- Apple III, 3:177
- Apple parers, 1:82–83
- Appleby, John, 1:304
- Apollo Project, 3:14–16
 - Apollo 1, 3:15
 - Apollo 8, 3:63
 - Apollo 11, 3:4, 15, 63, 76, 95
 - Apollo 13, 3:15
 - Apollo-Soyuz Test Project, 3:4
 - and Comsat/Intelsat, 3:42
 - cost of, 3:14, 15
 - criticism of, 3:15, 237
 - and Fairchild Semiconductors, 3:131–132
 - goal of, 3:14, 95
 - and Hamilton, Margaret, 3:62–63
 - and *Hidden Figures* (film), 3:74
 - and Johnson, Katherine Goble, 3:76, 155
 - largest scientific U.S. program, 3:14
 - and lunar surface samples, 3:15–16
 - Nike Air Tailwind, 3:11
 - and Skylab, 3:133–134
 - and Space Race, 3:14–15
 - termination of, 3:16, 237

- Apollo Applications Program (AAP), 3:133
 Apollo telescope mount (ATM), 3: 97, 3:133
 Argenti, Felice, 1:172
 Arithmometer, 2:113–114. *See also* Adding machines
 Arkwright, Richard, 1:101, 146, 147
 Armstrong, Edwin Howard, 2:246, 272
 Armstrong, Neil, 3:4, 15, 95
 Arnold, H. H. “Hap,” 2:261, 331–332
 ARPANET, 3:16–18
 and Defense Advanced Research Projects Agency (DARPA), 3:2–3, 16, 208
 and first e-book, 3:264
 first email sent, 3:17
 as forerunner to the Internet, 3:2–3, 16, 164, 190, 208, 300, 329
 funding for, 3:16
 and Metcalfe, Robert, 3:214
 origins of, 3:16–17, 300
 and packet switching, 3:17, 107
 Artificial heart, 3:180–181, 238
 Artificial intelligence (AI), 3:181–183
 AI effect, 3:183
 approaches to, 3:181–182
 definition of, 3:181
 ethical concerns of, 3:183
 future evolutions of, 3:190–191
 and fuzzy logic systems, 3:182
 implementation of at system level, 3:183
 and Minsky, Marvin, 3:90–91
 predicted by Kurzweil, Ray, 3:292
 problems in creation of, 3:181
 and statistics, 3:182
 TensorFlow (Google), 3:222
 Artificial memories, 3:258–259
 Aspartame, 3:18–19
 NutraSweet (brand name), 3:18–19
 public health concerns, 3:19
 and saccharine, 2:137; 3:18–19
 Asphalt, 2:17–18
 invention of modern road asphalt, 2:17
 natural asphalt (La Brea Tar Pits), 2:18
 used for Alaska Highway, 2:258
 Aspirin, 2:18–19
 Assembly line, 2:179–181
 automated flour mill’s influence on, 1:107
 conveyer system, 2:180
 and crayons, 2:46
 and Ford, Henry, 2:170, 179–180, 182, 203, 204; 3:49
 history and invention of, 2:179
 and interchangeable parts, 1:118, 119
 and liberty ships, 2:294
 moving chassis, 2:180, 182
 myth of invention by Ford, Henry, 2:179
 and Olds, Ransom Eli, 2:225
 primary document: excerpt from Henry Ford’s “The First Assembly Line” (1913), 2:181
 stationary, 2:225
 supply chain development, 2:180
 Association for Women in Mathematics (AWM), 3:19–20
 Astor, John Jacob, IV, 2:2, 107
 Astronomical almanacs, 1:11–12
 An Almanac for New England for the Year 1639 (first American almanac), 1:11
 Astronomical Diary and Almanack (Ames’s *Almanack*), 1:11, 12
 The Old Farmer’s Almanac, 1:11
 Pennsylvania, Delaware, Maryland and Virginia Almanack and Ephemeris, 1:15
 Rhode-Island Almanack, 1:11, 15
 Poor Richard’s Almanack, 1:11, 12, 13, 26
 Poor Robin’s Almanack, 1:11
 primary document: aphorisms from *Poor Richard’s Almanack* (1732–1758), 1:13
 AT&T. *See* American Telephone and Telegraph Company
 Atari, 3:20–22, 132
 home computers, 3:20, 22
 Jobs, Steve, game designer at, 3:209, 244
 lawsuit and intellectual property rights, 3:22
 Pong, 3:20, 21–22, 119–120, 321
 success of, 3:20–22, 321
 virtual reality version of, 3:323
 Atomic bombs/nuclear weapons, 2:260–261
 Fat Man and Little Boy (atomic bombs dropped on Japan), 2:261, 297
 Hiroshima and Nagasaki attacks, 2:260–261, 272, 283, 297, 300, 303; 3:220
 history of, 2:260
 Trinity test (first U.S. nuclear test), 2:260, 272, 297, 303
 See also Manhattan Project
 Automobile technologies (pre–World War II), 2:181–183
 assembly line, 2:179–181, 182, 203, 204
 “Big Three” U.S. automobile makers, 2:183
 closed-body cars, 2:182
 company competition, 2:182
 fenders, 2:181, 183
 Great Depression’s effect on, 2:182
 hydraulic brakes, 2:181, 182
 reinforced glass, 2:182–183
 transitional phase, 2:181
 V8 engine, 2:181, 182
 Vintage Era, 2:181–183
 Y Job fender, 2:183
 Automotive technologies (post–World War II), 3:22–24
 automatic transmissions, 3:23
 battery and energy storage technologies, 3:23
 “Big Three” U.S. automobile makers, 3:22
 and dynamic obsolescence, 3:22
 electric vehicles (EVs), 3:23, 49–53, 247, 281

- electronic and computer systems, 3:23
- and Federal-Aid Highway Act (1956), 3:23
- and government regulations, 3:23
- hybrid-electric vehicles (HEVs), 3:23, 49–53, 247, 281–283
- independent suspensions, 3:23
- and post-war consumer demand, 3:22
- safety technologies, 3:23
- V8 engine, 3:22–23
- Avenger Field, 2:261–263
 - home of Women Airforce Service Pilots (WASPs) of World War II, 2:261–262
 - primary document: letters of Mary Anna Martin Wyall, WASP pilot trainee (1944), 2:262–263
- Ayers, Robert, 1:95–96, 173
- B-17 Flying Fortress, 2:263–264
- Babbitt, Isaac, 1:179–180
- Babbitt, Sarah “Tabitha” (1779–1853), 1:84, 97
- Babbitt metal, 1:179–180
- Bacon, Roger, 1:11
- Bakeland, Leo Hendrik, 2:183–184
- Baer, Ralph (1922–2014), 3:24–25
 - Brown Box (first home video console), 3:24
 - as “Father of Video Game,” 3:24
 - primary document: excerpt from paper describing plans for simple video games (1966), 3:25
- Bailey, Robert, 1:11
- Baird v. Eisenstadt*, 3:32
- Bakelite, 2:183–185
- Ball bearings and Babbitt metal, 1:179–180
- Ballard, Martha (1735–1812), 1:75, 84–85
 - on currency, 1:85–86
 - diary of, 1:85
 - and *A Midwife’s Tale* (based on Ballard’s diaries), 1:86
 - on midwifery, 1:85
 - primary document: diary excerpts describing home weaving, 1:39–40
 - on textile work, 1:39–40, 86
 - on violence against women, 1:86
- Baltimore and Ohio (B&O) Railroad, 1:310
 - competition with Chesapeake and Ohio Canal, 1:94
 - oldest U.S. railroad, 1:7, 275, 289
 - Tom Thumb* (first U.S. steam engine) created for, 1:7; 2:150, 153
- Band-Aid, 1:175; 2:175, 185
- Banjo clock, 1:87
- Banneker, Benjamin (1731–1806), 1:13–15
 - almanacs of, 1:11, 12, 13–14, 15, 177
 - primary document: letter from Thomas Jefferson expressing that blacks had talents equal to other races (1791), 1:14–15
 - primary document: frontispiece of *Pennsylvania, Delaware, Maryland and Virginia Almanack and Ephemeris* (1792), 1:15
- solar eclipses studied by, 1:13, 77
- Bar code scanner, 3:25–27
 - RFID tag as alternative to, 3:306, 307
- Baran, Paul, 3:17, 107
- Barbed wire, 2:4, 19–23, 196
 - controversial wartime use of, 2:20
 - and history of wire, 1:19
 - invention of, 2:19
 - primary document: article excerpt on Joseph F. Glidden and the barb-wire industry (1884), 2:21–23
- Bardeen, John, 3:1, 131, 140, 148
- Barnum, P. T., 1:10, 184; 2:30–31
- Barton, Clara, 1:84–85
 - Civil War nurse, 1:191
 - primary document: “The Women Who Went to the Field” (1892), 1:192–193
 - Red Cross founded by, 1:264, 306
- Bashen, Janet (1957–), 3:259
- Batteries, 2:23
 - in artificial hearts, 3:181
 - and Edison, Thomas, 2:59
 - in electric and hybrid-electric vehicles, 2:23; 3:23, 49–53, 247, 282
 - in electric doorbells, 1:123
 - and electromagnets, 1:199
 - and environmental concerns, 2:23
 - in portable electronics, 3:165, 166, 251, 286
 - rechargeable, 2:23, 38
 - in smoke detectors, 3:136
 - in transistor radios, 3:148
 - in urban electrification, 2:63
- Bayer, Friedrich, 2:18–19
- Bayer & Company, 2:18–19
- Bee smoker, 2:24–25
 - primary document: excerpt from Moses Quinby’s *Mysteries of Bee-Keeping Explained* (1853), 2:24–25
- Beecher, Catherine, 1:170
- Bell, Alexander Graham (1847–1922), 2:26–28
 - biographical details, 2:26
 - credited with first practical telephone, 2:5, 26–27, 322–325; 3:329
 - and invention of the phonograph, 2:117, 209
 - metal detector invented by, 2:97–98
 - primary document: letter to parents describing idea for the telephone (1874), 2: 27–28
- Bell, Patrick, 1:205
- Bell Telephone Laboratories (Bell Labs), 2:16, 185–186, 324
 - Advanced Mobile Phone System (AMPS) developed by, 3:218
 - Multiplexed Information and Computing Service (MULTICS), 3:314
 - transistor created at, 2:17, 324; 3:131
 - vocoder created at, 3:155

- Bellanca, Dorothy Jacobs, 2:15
- Benedictus, Edouard, 2:183
- Benerito, Ruth Rogan (1916–2013), 3:27
 permanent press fabric invented by, 3:27, 111–112
 wash-and-wear cotton fabrics developed by, 3:27
- Benham, Rhoda W., 3:13
- Benz, Karl, 2:181
- Berlin Wall, fall of, 3:164
- Berliner, Emile (1851–1929), 2:29–30
- Berners-Lee, Tim (1955–), 3:184–185
 at CERN, 3:165, 184, 208
 and creation of World Wide Web, 3:163, 165–166, 184–185
 HTML developed by, 3:165, 184, 208, 300
 HTTP developed by, 3:165, 208, 184
 URL developed by, 3:184, 208
 World Wide Web Consortium (W3C) founded by, 3:184, 209
- Berry, George Stockton, 1:205
- Bessemer, Henry, 2:1, 34–36, 89–90, 139–140, 160, 201
- Bessemer steel, 2:35–36, 89, 139–140
- Best Friend* steam engine, 1:181
- Bifocals, 1:16–17
 bifocal and progressive contact lenses, 1:17
 invention of, 1:4, 16, 26
 primary document: Benjamin Franklin's letter describing his invention of bifocals (1725), 1:17
- Big science, 2:264–265
- Bilas (Spence), Frances, 3:1, 56
- Binney, Edwin, 2:45–46, 186–187
- Binney, Joseph, 2:46, 186
- Binney & Smith Inc., 2:46, 186–187
- Biodiesel, 3:27–38
 primary document: statement of Anne Steckel to Senate committee (2016), 3:29–31
- Birdseye, Clarence (1886–1956), 2:187–188
- Bishop, John Michael, 3:261
- Bissell, George, 2:90
- Bissell, Melville Reuben, 2:38
- Blacksmithing. *See* Iron- and silversmithing
- Blackwell, Elizabeth (1821–1910), 1:87–91
 primary document: excerpts from “Address on the Medical Education of Women” (1863), 1:89–91
- Blackwell, Emily, 1:88–91
- Blanchard, Thomas, 1:74–75, 244
- Blender, 2:188
- Blizzard Entertainment, 3:260
- Blodgett, Katherine (1898–1979), 2:188–189
- Blood transfusion, 2:173, 199, 265–266; 3:172
- Boeing, William E. (1881–1956), 2:189–190
- Boeing Company, 2:178, 189–190; 3:232, 237, 302
- Boggs, David, 3:215
- Boggs, Hale, 2:288
- Bohr, Niels, 3:80, 305
- Bomb disposal robots/units, 3:33
- Bomford, George, 1:204–205
- Borden, Gail, III, 1:173
- Boston Associates, 1:147, 161
- Boston Tunnel, 3:185–186
- Bottle-making machine, 2:190–191
- Bowditch, Nathaniel, 1:75–76, 77, 137
- Bradberry, Henrietta (1903–1979), 2:266–267
- Brandeis Brief (*Muller v. Oregon*), 2:104, 172
- Brattain, Walter, 3:1, 131, 148
- Bread slicer and wrapping machine, 2:191
- Breast pump, 1:182
- Brill, Yvonne Madalaine Claeys (1924–2013), 3:34–35
 primary document: patent for new jet propulsion technology (1974), 3:35
- Brooklyn Bridge, 2:30–31
 construction of, 2:30
 as National Historic Landmark, 2:31, 132
 primary document: photograph of promenade on Brooklyn Bridge, 2:131
 renovation (2010–2015), 2:31
- Brown, Harold Pitney, 2:62
- Brown, Josiah, Jr., 1:182–183
- Brown, Louise, 3:70
- Brown, Marie Van Brittan (1922–1999), 3:35
- Brown, Moses, 1:146–147
- Brown, Rachel Fuller, 3:5, 13–14
- Brown, William, 1:282
- Brown Box (first home video console), 3:24
- Brown Ferry Plant (nuclear plant), 2:329
- Brown Truss, 1:182–183
- Brown v. Board of Education*, 2:52
- Brownie (Kodak camera), 2:33, 57, 120, 133, 171
- Browning, John M. (1855–1926), 1:248–249
- Brownson, Orestes, 1:168, 171
- Bryant, Alice (1862–1942), 2:192
- Buchner, Joseph, 2:18
- Bulletproof vest/Kevlar, 3:36, 77
- Bullock, William, 1:174, 271
- Burglar alarm, 1:183
- Burks, Arthur, 3:55
- Burr, Theodore, 1:91–92
- Burr truss bridge, 1:91–92
- Burroughs, William S., 2:14, 114
- Burt, William Austin, 1:168, 225–226, 287
- Bush, George H. W., 3:197
- Bush, George W., 3:12, 72, 90, 239, 240, 319
- Bushnell, David (1740–c. 1824), 1:17
 primary document: engraving of American *Turtle* (1775), 1:18
 primary document: letter to Thomas Jefferson regarding experiments, 1:66–67

- Turtle* submarine created by, 1:17–18, 65, 301
 Bushnell, Nolan, 3:20–22, 119–120
- Calculators**
 Clarke Calculator (graphing calculator), 2:268
 digital logarithmic converter, 3:326
 electromechanical calculator, 3:69
 handheld calculators, 3:68, 77, 326
 and history of personal computers, 3:223–224
 microprocessors used in, 3:133
 mobile phones as, 3:219
 photovoltaic cells used in, 3:235
See also Adding machines
- Calliope (steam organ), 1:183–185
 Calutron Girls, 2:267–268
 Camera, 2:31–33
 Brownie (Kodak), 2:33, 57, 120, 133, 171
 daguerreotype, 2:31–32, 120
 digital photography, 3:167, 193–195
 first recorded movie, 2:33
 history of, 3:31–33
 in home security systems, 3:35
 photographic film, 2:120–121
 photography of Civil War, 1:256
 pinhole cameras, 2:31
 Polaroids, 3:79–80, 117–118
 in space probes, 3:75, 156, 297
 in stealth aircraft, 3:140
 in virtual reality technology, 3:324, 325
 Can opener, 3:33–34
 Canals, 1:92–95
 American canal systems, 1:6, 94
 Bridgewater Canal, 1:93
 Chesapeake and Ohio Canal, 1:94
 early canal building, 1:6
 and lamp oil discovery, 2:90
 and Industrial Revolution, 1:93
 Middlesex Canal, 1:6, 93
 oldest known American canal, 1:93
 purpose of, 1:92–93
See also Erie Canal; Panama Canal
- Cancer research, 3:261–252
 American Cancer Society (ACS), 3:262
 Cancer Genome Atlas (TCGA), 3:262
 contributions of American organizations, 3:261
 discoveries by American scientists, 3:261
 and National Cancer Act (1971), 3:261
 National Cancer Institute, 3:261–262
 Philadelphia chromosome, 3:262
- Canning factory, 1:95–96
 Cannon, Annie Jump (1863–1941), 2:192–193
 Cannon, double-barrel, 1:185–186
 primary document: excerpt from memoirs of Edward Porter Alexander on “artillery hell” at Antietam (1907), 1:186
- Carbutt, John, 2:43
 Carey (Agassiz), Elizabeth Cabot, 1:176
 Carey, Henry Charles, 1:167, 171–172
 Carnegie, Andrew (1836–1919), 2:34–35
 biographical details, 2:34, 35–36
 Carnegie Steel Company founded by, 2:34–35
 and Gilded Age “robber barons,” 2:34
 and U.S. Steel, 2:34
 Carnegie Steel Mill, 2:1, 35–37
 and competitive advantage, 2:36–37
 and cost control, 2:36
 and Panic of 1873, 2:35, 36
 primary document: correspondence of Andrew Carnegie and Henry Clay Frick regarding the Homestead Strike (1892), 2:35, 37
 purchased by Morgan, J. P., 2:35, 36–37
 and vertical integration, 2:34–36
 Carothers, Wallace (1896–1937), 2:194; 3:7
 Carpet sweeper, 2:38
 Carson, Rachel (1907–1964), 3:36–38
The Edge of the Sea, 3:37
 and public suspicion of chemical products, 3:18
The Sea Around Us, 3:6, 37
Silent Spring, 2:288–289; 3:6–7, 18, 36–38, 129–130
 Carter, Jimmy, 2:105, 228; 3:104, 113, 129, 139, 272
 Carver, George Washington (1861–1943), 2:38–39
 crop rotation innovations by, 2:39–40
 and peanut products, 2:39
 primary document: George Washington Carver addresses Congress (1921), 2:41–42
 Cash register, 2:42
 Cassini Saturn Mission, 3:127, 262–263
 discoveries of, 3:262–263
 and Jet Propulsion Laboratory (JPL), 3:75
 purpose of, 3:262
 Cayley, George, 2:165, 176
 CD and DVD, 3:186–188
 CD-ROM, 3:188–189
 Cellophane, 2:53
 Cellophane tape, 2:113, 218, 241, 253
 Celluloid, 2:42–43
 Centers for Disease Control and Prevention (CDC)
 AIDS research, 3:171, 173–174
 Jemison, Mae, at, 3:290
 polio vaccine recommendations, 3:118
 CERN (Conseil Européen pour la Recherche Nucléaire, or European Council for Nuclear Research), 3:108, 165, 184, 208
 primary document: press release, 3:109–110
 Channing, William Francis, 1:227–228
 Charpentier, Jean de, 1:176
 Charting the Gulf Stream, 1:96–97
 Child labor, 1:162, 298; 2:2, 7, 104–105
 Chlorofluorocarbons (CFCs), 3:38–39

- and aerosol spray cans, 2:176
- and Freon, 2:204–205, 220, 311; 3:38, 192
- invention of, 2:219–220; 3:38
- Christian, Charlie, 2:270–271
- Christmas tree lights, 2:194–195
- Chu, Jeffrey Chuan, 3:55
- Chuck wagon, 2:195–196
- Circular saw, 1:97–98
- Civil War medicine (1861–1865), 1:186–190
 - amputations, 1:188
 - hospitals, 1:187–188
 - long-term care, 1:188
 - primary document: report on Union casualties suffered at the Battle of Shiloh (1862), 1:188–190
 - and United States Sanitary Commission (USSC), 1:187, 306–307
 - wartime deaths, 2:186–187
 - wound treatment and surgery, 1:187–188
- Civil War nursing, 1:190–193
 - and Catholic sisters, 1:191
 - primary document: Clara Barton's poem "The Women Who Went to the Field" (1892), 1:192–193
 - race and class structure of, 1:191
- Civilian Pilot Training Program (CPTP), 2:261
- Clark, Barney, 3:180
- Clark, James H., 3:301
- Clark, William, 1:8, 123–127. *See also* Lewis and Clark Expedition
- Clarke, Edith (1883–1959), 2:268
- Clarke, William Edward, 1:178
- Clarke calculator, 2:268
- Clarke School for the Deaf, 2:26
- Climate change, 3:39–41
 - and carbon capture and storage (CCS), 3:40
 - causes of, 3:39
 - and dams, 2:213
 - disagreements and controversy, 3:39
 - and Freon, 2:311
 - and *An Inconvenient Truth* (documentary), 3:39
 - and Kyoto Treaty, 3:40
 - and Paris Agreement, 3:41
 - and solar radiation management, 3:40
 - and urban electrification, 2:65
- Clinton, Bill, 3:227
 - and International Space Station, 3:284
 - and Kyoto Treaty, 3:40
 - military reduced by, 3:90
- Clinton, Hillary, 3:323
- Clipper ship, 1:194–196
 - Baltimore clippers, 1:194
 - packet ships, 1:194
 - primary document: journal excerpts of Alexander Van Valen describing journey to California via clipper ship (1849), 1:196
 - Rainbow* (considered first true clipper), 1:194
- Clothespin, 1:196–197
- CO₂ welding, 3:41
- Coal-mining technologies, 1:197–198
 - and damp (gas pockets), 1:198
 - early coal mining, 1:198
 - and labor unions, 1:198
 - safety of, 1:198
 - stripmining, 1:197
 - surface mining, 1:197
 - underground mining, 1:197–198
- Coca-Cola, 2:43–44
- Cochran, Jacqueline, 2:263, 331–332
 - and formation of Women's Airforce Service Pilots (WASPs), 2:331–332
 - Women's Flying Training Detachment (WFTD) director, 2:261, 332
- Cochran, Josephine, 2:4, 48–49
- Coffee percolator, 1:98–99
- Coil magnet/electromagnet, 1:199
- Cold War (1946–1979), 3:1–8
 - advances in biological science and medicine, 3:4
 - dawn of computer science, 3:1
 - definition of, 3:1
 - environmental activism, 3:6–7
 - global communications and Internet, 3:2–3
 - nuclear arms and nuclear power, 3:5–6
 - rapid technological change, 3:1
 - Space Race, 3:3–4
 - widespread use of synthetic materials, 3:7
- Colden, Jane (1724–1766), 1:19–20, 45
- Colgate, William (1783–1857), 1:200
- Collier, Ralph, 1:222
- Colton, Gardner Quincy, 1:178
- Colonial America and Enlightenment society, 1:1–8
 - as "Age of Reason," 1:1
 - cotton industry, 1:5–6
 - economics of colonial settlements, 1:2–3
 - and England's Iron Act (1750), 1:3
 - harnessing electricity, 1:1
 - indigenous people's experience, 1:2
 - and Industrial Revolution, 1:4–5
 - Jamestown colony, 1:2, 38
 - and mercantile system, 1:3, 5, 60–61, 138
 - putting-out production replaced by factory system, 1:4, 5
 - study of natural sciences, 1:3–4
 - transportation advances, 1:1
- Colored Female Free Produce Society, 1:201–202
- Colt, Samuel (1814–1862), 1:202–203
 - Colt Patent Fire-Arms Manufacturing Company, 1:202
- Colt revolver, 1:203–204
- Columbiad Cannon, 1:204–205
- Colvin, Margaret, 2:4, 134
- Combine harvester, 1:205–207

- Commodore 64, 3:42, 224
- Compact iron stove, 1:207–208
- Comptometer, 2:113–114. *See also* Adding machines
- Computer/information technology, 3:189–191. *See also*
 Apple; Apple II; Commodore 64; IBM personal computer; Personal computer
- Comsat/Intelsat, 3:42–43
 and Communications Satellite Act (1962), 3:2, 42
 creation of COMSAT Corporation, 3:2
 Intelsat I (first operational satellite), 3:42
- Comstock Law (1873), 3:32
- Conestoga wagon, 1:208–211
 primary document: excerpt from John G. Abbott's
 recollections of traveling to California by wagon train
 (1852), 1:210–211
- Constitution. *See* United States Constitution
- Constitutional Convention (1776), 1:53
- Constitutional Convention (1787), 1:26, 112, 136
- Cook, Tim, 3:179
- Coolidge, Calvin, 2:174, 237
- Coolidge, William D., 2:199–200
- Cooper, Gordon, 3:88
- Cooper, Leon Neil, 3:140–141
- Cooper, Martin, 3:218
- Cooper, Peter
 first steam-powered locomotive (*Tom Thumb*) created by,
 1:7, 150, 289; 2:150
 grandfather to Hewitt, Peter C., 2:210
 primary document: John Latrobe's description of *Tom
 Thumb*, 2:150–152
 wrought iron beams pioneered by, 2:139
- Cooper pairs, 3:141
- Corn sheller, 1:211
- Corps of Discovery. *See* Lewis and Clark Expedition
- Corset, 1:211–213
- Coston, Martha (1826–1904), 1:213
- Cotton candy machine, 2:45
- Cotton gin, 1:99–101, 119
 and demand for cotton, 1:101
 Greene, Catharine Littlefield, as coinventor of, 1:5, 116,
 117, 164–165
 influence and legacy of, 1:5, 74, 82, 86, 99–100
 invention of, 1:5, 99, 164–165
 and spinning wheel, 1:60, 61
 and Waltham-Lowell textile system, 1:161
- Cotton sewing thread, 1:101
- Cowboy hat (Stetson), 1:213–214
- Crane, Clarence, 2:217
- Cray, Seymour (1925–1996), 3:191–192
- Crayons, 2:45–46
- Crick, Francis, 3:5, 202
- Crocker, Charles, 1:275, 290
- Crosby, Caresse. *See* Jacob, Mary Phelps
- Crosley Motors, 2:182
- Crump, Scott, 3:316
- Crumpler, Rebecca (1831–1895), 1:214–215
- Crystal Palace Exhibition. *See* Great Exhibition of 1851
 (London)
- Curanderas*, 3:43–45
- Curling iron, 2:47
- Curtiss-Wright Aeronautical Engineering Cadettes,
 2:269–270
- Cuvier, Georges, 1:176
- Cylinder pin tumbler lock, 1:216
- Czarnecki, Kazimierz, 3:73
- D rations, 2:270, 300
- da Vinci, Leonardo, 2:143
 and flying machines, 2:176, 177
 gas engine prototype, 2:247
 and pedometer, 1:122
 pinhole camera used by, 2:31
 and underwater sound waves, 2:318
- da Vinci Surgical System, 3:229, 230–232, 250
- Dabney, Ted, 3:20–22, 119–120
- Daguerre, Louis, 2:31–32, 130
- Dahlgren gun, 1:216–217
- Dark matter science, 3:45–47
- Darken, Joanne, 3:19
- Dart, Joseph, 1:233–234
- Darwin, Charles
 American Philosophical Society member, 1:9
 evolution theory opposed by Agassiz, Louis,
 1:175, 176
 Gosling, James, on Darwinism, computers, and human
 evolution, 3:289
 and Haeckel, Ernst, 2:129
 Hawking, Stephen, compared to, 3:277
 Rush, Benjamin, on, 1:145
 on “selective breeding,” 3:202
- Davidson, Arthur, 2:221–222
- Davis, Donald, 3:107
- Davis, Jack, 3:35
- Davis, Jan, 3:291
- Davy, Humphry
 arc lamp of, 1:198
 nitrous oxide experiments of, 1:246, 247
 and short electric arc, 1:116, 198
- Daylight Saving Time, 1:20
- DDT (dichlorodiphenyltrichloroethane), 2:301; 3:6, 18, 36,
 38, 130
- de Forest, Lee (1873–1961), 2:196–197
- de la Peña, Carolyn, 2:136; 3:19
- de Smedt, Edward J., 2:17–18
- Deductive reasoning, 1:1, 3, 7
- Deere, John (1804–1886) and Deere and Company, 1:159,
 205, 217–220
 polished steel plow invented by, 1:171, 217–218, 269

- Defense Advanced Research Projects Agency (DARPA), 3:2–3, 16, 208. *See also* ARPANET
- Dell, Michael “Saul” (1965–), 3:192–193
- Demikhov, Vladimir, 3:180
- Demorest, Ellen Curtis, 1:286
- Denison, Lester E., 1:211
- Denny, James, 3:19
- Denny, Reginald, 3:48
- Dental chair, 1:219
- Dental floss, 1:102–103
- Detachable collar, 1:219–220
- Dexter, Henrietta F., 3:13
- Dickelman, Elizabeth (dates unknown), 2:197
- Dickerson, Mary Cynthia (1866–1923), 2:197–198
- Diesel, Rudolph, 3:28
- Diffraction grating, 1:103
- Digital photography, 3:193–195
primary document: excerpt from patent for Kodak’s digital camera (1978), 3:195
- Diner (horse-drawn), 2:47–48
- Dishwashing machine, 2:48–49
- Dix, Dorothea (1802–1887), 1:220–221, 308
activist for mentally ill, 1:220–221
Civil War superintendent of army nurses, 1:187, 191, 221, 264
and U.S. Sanitary Commission (USSC), 1:306
- DNA (deoxyribonucleic acid), 3:4–5, 93, 109, 153, 196
gene patenting, 3:270–271
genetic engineering, 3:201–205
genetically modified foods, 3:271–273
Human Genome Project, 3:279–280
- Dolby Laboratories, 3:47
- Dow Chemical Company, 2:49–50
- Drake equation, 3:264
- Dred Scott v. Sandford*, 1:172
- Drew, Charles (1904–1950), 2:198–199
- Drones, 3:48–49
and Amazon package delivery, 3:258
and artificial intelligence, 3:183
drone warfare, 2:301–302; 3:48
electroexpulsive technology used in, 3:255
history of, 3:48
“Lightning Bugs,” 3:49
as natural progression of helicopter technology, 2:277
Predator missiles, 3:48
Quail decoy drone, 3:140
and stealth technology, 3:140
in World War I, 3:48
World War II German drones, 2:301–302
- Du Mont, Allen B., 1:78
- du Pont, Éleuthère Irénée, 1:77
- du Pont, Pierre (1870–1954), 2:50–52
- Duct tape, 1:175; 2:256. *See also* Adhesive tape
- Ductile tungsten, 2:199–200
- Dudley, Benjamin, 1:246–247
- Dudley, Homer, 3:155
- DuPont Company, 1:77; 2:52–54
- Duprey, Ana Roqué de (1853–1933), 2:54
- Duryea, Charles (1861–1938) and Frank (1869–1967), 2:54–55
- Dust Bowl
and Lend-Lease Program, 2:294
photographs by Lange, Dorothea, of, 2:292–293
overfarming as cause of, 1:207
- Dustpan, 1:221–222
- Earth Resources Technology Satellite (ERTS-1), 3:2
- Ebers Papyrus (Egyptian medical scroll of herbal knowledge), 2:18
- e-book and e-reader, 3:264–266
Kindle, 3:251, 258, 265, 312
- e-Sports, 3:267–268
- Earl, Harley, 2:183
- Earmuffs, 2:55
- Eastman, George (1854–1932), 2:56
- Eastman Kodak Company, 2:56–57
- Eckert, John Presper, 3:55, 150–151
- Eckert-Mauchly Computer Corporation, 3:65, 69
- Edison, Thomas (1847–1931), 2:5, 40, 43, 57–59, 143, 194–195, 324
biographical details, 2:57–58
direct current system, 2:107, 147–148
and Ford, Henry, 2:59, 203
Kinematoscope, 2:6, 91, 103
lightbulb patented by, 2:47, 58
and motion pictures, 2:243–244
phonograph invented by, 2:115–118, 208–210
quadruplex telegraph invented by, 2:26, 124–125
- Edison effect, 2:196
- Edison Electric Light Company, 2:5, 61, 194
- Edison General Electric Company, 2:74
- Edwards, Robert, 3:70
- Eggbeater, 1:222
- Eichengrün, Arthur, 2:19
- Einstein, Albert (1879–1955), 2:199–201, 224, 260, 271–272, 304, 317
biographical details, 2:199–200
on dangers of nuclear weapons, 3:201, 111
photoelectric effect defined by, 3:235
and quantum science, 3:304–305
stimulated emissions theory proposed by, 3:80
- Eisenhower, Dwight D.
Atoms for Peace program, 3:6, 128
election of 1952, 3:151
and Federal-Aid Highway Act (1956), 3:23
and military-industrial complex, 3:88–90
NASA established by, 3:3, 94, 137

- and oil quotas, 3:112
- primary document: letter to Glennan, Keith, retiring administrator of NASA, 3:98
- and Shippingport Atomic Power Station, 3:128–129
- Electric car, 3:49–53, 247, 281
 - primary document: article from the energy.gov web site (2014), 3:50–53
- Electric doorbell, 1:223–224
- Electric guitar, 2:270–271
- Electric iron, 2:59–60
- Electric lightbulb, 2:60–61
- Electric stove, 1:223
- Electric street railway, 1:223–224
- Electrical tape, 1:175. *See also* Adhesive tape
- Electricity, war of the currents, 2:61–63
- Electrification, urban, 2:63–65
- Electroexpulsive technology, 3:254–255
- Electromagnetic induction, 1:7, 168, 237; 2:10–11, 323. *See also* AC induction motor
- Electronic Numerical Integrator and Computer. *See* ENIAC and the “ENIAC Girls”
- Elevator safety brake, 1:224–225
- Elion, Gertrude (1918–1999), 3:195–197
- Emerson, Ralph Waldo, 1:168, 171
- Empire State Building, 2:201–202
- Enders, John Franklin (1897–1985), 3:4, 54
- Engelbart, Douglas (1925–2013), 3:3, 55
- ENIAC and the “ENIAC Girls,” 3:1, 55–56
 - designers, 3:55, 151
 - first electronic general-purpose computer, 3:55
 - programmers (ENIAC Girls), 3:56
 - purpose of, 3:55, 189
- Enlightenment
 - and consequences of change, 1:7–8
 - and deductive reasoning, 1:1, 3, 7
 - impact of, 1:1
 - and inoculation, 3:151–152
 - population redistribution, 1:8
 - Tesla, Nikola, on Niagara Falls Power Plant as testament to, 2:110
- See also* Colonial America and Enlightenment society
- Equatorial sextant, 1:168, 225–226, 287
- Erie Canal, 1:104–107, 245
 - construction of, 1:6, 105
 - importance and legacy of, 1:6, 76, 78, 83, 94, 105, 233
 - primary document: letter of Robert Fulton to George Washington urging construction of canals (1797), 1:106–107
 - and steam railroad construction, 1:7, 105, 293
- Escalator, 2:65–67
- Ethernet, 3:132, 190, 214–215
- Evans, Oliver (1755–1819), 1:79–81, 107–109
 - biographical details, 1:79, 107
- first amphibious steam vehicle (*Oruktor Amphibolos*) built by, 1:79–80, 107, 118
- high-pressure steam engine developed by, 1:117–118
- ice-making machine designed by, 1:161, 268
- influence of, 1:73–74, 76–77, 107–108, 117–118
- and patent conflict with Jefferson, Thomas, 1:108–109, 136
- Mars Iron Works founded by, 1:118
- primary document: image of amphibious steam vehicle (1834), 1:81
- primary document: letters to Thomas Jefferson (1804, 1808), 1:108–109
- steam-powered flour mill invented by, 1:73–74, 107, 107–108, 234
- The Young Millwright and Miller’s Guide*, 1:73, 107
- Explorer (browser). *See* Internet Explorer
- Explorer I, 3:3, 74, 92, 93, 95, 121
- Extension arm (long arm), 1:21
- Extinction, species, 1:47, 175, 176; 3:250
- Facebook, 3:268–270
- Fahlberg, Constantin, 2:135–136; 3:18
- Fairbanks, Erastus, 1:168; 2:268–269
- Fairbanks, Thaddeus, 1:168, 268–269, 291
- Falconer, Etta, 3:20
- Faraday, Michael, 1:7, 168, 237; 2:10, 323
- Farber, Sidney, 3:261
- Federal-Aid Highway Act (1956), 2:287–290
 - primary document: excerpt from the Federal-Aid Highway Act (1956), 2:289–290
- Fender, Leo, 2:271
- Fermi, Enrico (1901–1954), 2:260, 271–272, 283, 296, 331
- Ferraris, Galileo, 2:10
- Ferris wheel, 2:66–68
 - primary document: telegrams between Luther Rice and George Ferris on successful test of the Ferris wheel (1893), 2:68
- Feynman, Richard P., 2:260, 317; 3:93
- Field, Cyrus West (1819–1892), 1:226–227; 2:5
- Finely, Susan, 3:121
- Fire alarm call box, 1:227–228
- Fire hydrant, 1:109–111
 - primary document: account of the Detroit Fire (1805), 1:110–111
- Fire Safety, 1:21–22
- Fitch, John (1743–1798), 1:76, 111–112
 - biographical details, 1:111
 - first successful steam-powered boat developed by, 1:111–112, 115, 151
 - monopoly granted to, 1:111–112, 136, 293
- Fitzroy, Nancy DeLoye, 1:78
- Flatboat, 1:112–114
- Flexible catheter, 1:22–23

- Floating dry dock (1849), 1:228–230
 primary document: excerpt from Abraham Lincoln's patent application for the floating dry dock (1849), 1:229–230
- Floppy disk, 3:197–198
- FM radio, 2:272–273
- Folding cabinet bed, 2:68–70
 primary document: patent for folding cabinet bed (1885), 2:69–70
- Folger, Timothy, 1:96–97
- Folsom, Joseph Libbey, 1:172
- Food and Drug Administration (FDA), 3:172
 and AIDS research, 3:172, 239
 and artificial sweeteners, 2:137; 3:18–19
 and birth control, 3:32, 307
 on cosmetic surgery, 3:249
 creation of, 2:172
 first female lab chief, 2:232
 and genetically modified foods, 3:272
 primary document: letter on regulation of robotic surgery (2013), 3:230–232
 and robotic surgery, 3:229, 230, 250
 and toothpaste categorization, 1:300
- Food preservation, 2:70–71
- Food production, Native American, 1:23–25
- Ford, Henry (1863–1947), 2:36, 40, 202–204
 and assembly line, 2:170, 179–181
 biographical details, 2:202–203
 and Edison, Thomas, 2:59, 203
 “Fordism,” 2:204
 Model A, 2:181, 203–204
 Model T, 2:170, 180, 182, 203–204
- Fortran, 3:56–57, 69, 121, 155
- Fossey, Dian (1932–1985), 3:198–199
- Fountain pen, 2:71–72
- Franklin, Benjamin (1706–1790), 1:4, 25–27
 American Philosophical Society created by, 1:4, 71–72
 electricity experiments, 1:4
 glass armonica invented by, 1:4, 31, 32
 primary document: letter describing experiments with electricity (c. 1750), 1:26–27
- Franklin, James, 1:11, 25
- Franklin stove, 1:27–31
 primary document: Excerpt from *An Account of the New Invented Pennsylvanian Fire-Places* (1744), 1:28–31
- Frasch process, 2:72–72
- Freeze-dried food, 2:273
- Freireich, Emil Jay, 3:261
- French and Indian War (1754–1763), 1:3, 35, 208
- Freon, 2:204–205, 215, 220, 311; 3:38, 192
- Frick, Henry Clay, 2:35
 primary document: correspondence with Andrew Carnegie regarding Homestead Strike (1892), 2:37
- Fugitive Slave Act (“Compromise of 1850”), 1:172
- Fuller, Richard Buckminster (1895–1983), 3:57–58
 primary document: drawing of R. Buckminster Fuller's Geodesic Dome (c. 1933), 3:58
- Fulton, Robert (1765–1815), 1:114–115
- Gaffer tape, 1:175. *See also* Adhesive tape
- Gagarin, Yuri, 3:4, 237
- Gallo, Robert, 3:172, 175
- Galvin, Joseph, 2:205
- Galvin, Paul Vincent (1895–1959), 2:205–206
 biographical details, 2:205
 mass production process of automotive radios created by, 2:205–206
 Motorola cofounded by, 2:182
 and Motorola 5T71 radio, 2:205–206
- Garbage disposal, 2:273–274
- Gas mask, 2:274
- Gas transmission, 2:73–74
- Gas tungsten arc welding, 1:115–116
- Gas well, 1:230
- Gates, Bill (1955–), 3:163, 199–201, 244
 on artificial intelligence, 3:183, 191
 Bill & Melinda Gates Foundation, 3:212, 199, 201, 270
 cofounder of Microsoft, 3:190, 199–201, 217, 218
 and Jobs, Steve, 3:211, 212
- Gatling, Richard, 1:174, 247–248
- Gene patenting, 3:270–271
- General Electric, 2:74–75
- General Motors (GM), 2:206–207
- Genetic engineering, 3:201–204
- Genetically modified foods, 3:271–273
- Geographic Information Systems (GIS), 3:164
- Gibbs, Mifflin Wistar, 1:173
- Gilbreth, Lillian (1878–1972), 2:208
- Gilleland, John, 1:185
- Gilpin, Thomas, 1:266
- Glass harmonica (Armonica), 1:30–32
 primary document: excerpt of Benjamin Franklin's letter describing the glass harmonica (1762), 1:32
- Glenn, John
 first manned satellite (Friendship 7) piloted by, 3:95
 Mercury 7 crew member, 3:88, 95
 oldest human to fly in space, 3:238
- Glenn, William, 3:180
- Glennan, Keith, 3:98, 137
- Glidden, Carlos, 2:155
- Glidden, Joseph F., 2:19–23
- Gliders, 2:165, 176–177
- Global Positioning System (GPS), 3:59–60
- Glover, Elizabeth (d. 1643), 1:32–33
- Goddard, Robert H., 2:312
- Godfrey, Thomas (1704–1749), 1:33–34
- Goeppert-Mayer, Maria (1906–1972), 3:60–61
- Gold-mining technologies, 1:231–232

- Golden Gate Bridge, 2:274–276
 primary document: letter of Charles Ellis to the *San Francisco Chronicle* (1930), 2:275–276
- Goldmann, Felix, 2:19
- Goldsmiths, 1:36, 180, 267. *See also* Iron- and silversmithing
- Goode, Sarah Elizabeth, 2:4, 68–70
- Goodhue, Lyle, 2:176
- Goodnight, Charles, 2:195–196
- Goodrich, B. F. (1841–1888), 2:75–76
- Goodyear, Charles (1800–1860), 1:232–233, 307–308
- Goodyear, Charles, Jr. (1833–1896), 2:76
- Google, 3:274–275
- Google Earth, 3:275–276
- Gorbachev, Mikhail, 3:164
- Gore, Al, 3:17, 39
- Gorelick (Ratley), Sarah, 3:88
- Gosling, James (1955–), 3:204
- Graham, Bette (1924–1980), 3:61–62
- Graham, Evarts Ambrose, 3:261
- Graham, Sylvester, 1:236
- Grain elevator, 1:233–234
- Gramophone/Victrola, 2:208–210
- Grandin, Temple (1947–), 3:276–277
- Gray, Elisha, 2:26–28, 323–324
- Gray, Mary, 3:20–21
- Great Depression and World War II (1930–1945), 2:251–257
 adhesive tape's popularity during, 2:241
 and automobile industry, 2:181–183, 204, 206, 207
 contribution to decline in railroad ridership, 1:290–291
 debut of Sunbeam's Mixmaster during, 1:222
 effect on farm equipment manufacturing, 1:206
 and end of Golden Age of amusement parks, 2:134
 and end of products and companies, 1:208; 2:210
 entertainment during, 2:255
 and food, 2:136, 145
 and Hoover, Herbert, 2:251
 and Hoover Dam, 2:251, 252, 277–283
 and labor response by Kellogg, William Keith, 2:88
 and radio, 2:237
 and Roosevelt, Franklin D., 2:251–254
 scientific advances during, 2:253–253
 and Tennessee Valley Authority (TVA), 2:251–252
 See also Dust Bowl; New Deal; Roosevelt, Franklin D.
- Great Exhibition of 1851 (London), 1:238; 2:162
 Colt Revolver at, 1:204
 equatorial sextant (solar compass) at, 1:225
 McCormick Reaper awarded grand prize at, 1:253
 omnibuses at, 1:265
 Otis elevator at, 2:139
 telegraph at, 1:310
- Greene, Catharine Littlefield (1755–1814), 1:116–117
- Grey, Henry, 2:140
- Gridiron for cooking, 1:234
- Griswold v. Connecticut*, 3:32
- Groves, Leslie R., 2:260
- Gumball machine, 2:210
- Gunsmiths, 1:174, 202, 203, 281, 243–244; 2:80. *See also* Iron- and silversmithing
- Gutenberg, Johann, 1:270–271
- Hadaway, William, 1:223
- Hall, David D., 1:1
- Hall, John, 1:74–75, 244, 281
- Halley, Edmund, 1:33, 96
- Hallidie, Andrew Smith (1836–1900), 2:76–77
- Halsted, William Stewart, 3:261
- Hamilton, Alexander, 1:8, 167; 3:128
 Report on Manufactures, 1:72, 138–139, 284
- Hamilton, Margaret (1936–), 3:62–63
- Hammes, John, 2:273
- Hammond, William, 1:187
- Han, Otto, 2:260
- Hanchett, Milton Waldo, 1:219
- Hand-cranked ice cream maker, 1:234–235
- Hanson, Alvah, 1:206
- Harley, Arthur, 2:221–222
- Harley-Davidson Motor Company, 2:221–222
- Harper, Frances Ellen Watkins, 1:201
- Hart, William, 1:230
- Harvard Computers, 2:77–79
 primary document: undated photo of Harvard Computers, 2:79
- Haslim, Leonard A., 3:254
- Hawking, Stephen (1942–2018), 3:277–278
- Hawkins, John Isaac, 1:16
- Haynes, Elwood (1857–1925), 2:79–80
- Haynes, Martha Euphemia Lofton (1890–1980), 3:63–64
- Hazen, Elizabeth, 3:5, 13–14
- Health reform, 1:235–237
- Heisenberg, Werner, 3:80, 305
- Helicopter, 2:276–277
- Helin, Eleanor Francis, 3:121
 primary document: press release naming Helin to WITI Hall of Fame, 3:122–123
- Henry, Benjamin Tyler, 1:174, 281
- Henry, Joseph (1797–1878), 1:78, 237–238
 biographical details, 1:237
 electric doorbell invented by, 1:199, 223
 and electromagnetic induction, 1:7, 237
 electromagnets designed by, 1:199, 237, 310
 electromechanical relay invented by, 1:169, 280
 and Morse, Samuel, 1:237, 261
 and National Academy of the Sciences, 1:238
 and Smithsonian Institution, 1:7, 237–238
 and U.S. Light-House Board, 1:237–238
- Henry rifle, 1:174
- Hershey, 2:173, 270, 300
- Hertz, Roy, 3:261

- Hewitt, Peter C. (1861–1921), 2:210–212
- Heydenfeldt, Solomon, 1:172–173
- Heyl, Henry (1842–1919), 2:80–81
- Hicks, Elias, 1:201
- High-pressure steam engine, 1:117–118
- Hilde, Libra R., 1:191
- Hillman, Bessie Abramowitz, 2:14–15
- Hillman, Sidney, 2:15
- Hinckley, Robert C., 1:178
- HIV. *See* AIDS research
- Hoe, Richard, 1:169, 271
- Hoffmann, Felix, 2:18–19
- Holland, James Frederick, 3:261
- Hoop skirt, 1:238–239
- Hoosier cabinet, 2:212
- Hoover, Erna, 3:143
- Hoover, Herbert, 2:88, 251
- Hoover Dam, 2:213, 277–283; 3:128
 environmental effects of, 2:213
 and Great Depression, 2:251, 252, 277–283
 primary document: Franklin D. Roosevelt’s dedication
 speech, 2:280–283
- Hopkins, Mark, 1:290
- Hopper, Grace (1906–1992), 3:1, 65–66
- Horse-drawn streetcar, 1:239–240
 primary document: image of horse-drawn streetcar (c. 1920),
 1:240
- Hospital Transport Service, Women’s Department, 1:240–241
- Hot air balloon, 2:176–177
- House, Royal E., 1:169, 272
- Howe, Elias (1819–1867), 1:241–242
 Automatic, Continuous Clothing Closure patent, 1:311
 biographical details, 1:241–242
 mechanized sewing machine patent, 1:5–6, 171, 242, 285,
 311
 patent battle with Singer, Isaac, 1:6, 285
 transverse shuttle invented by, 1:171, 303
- Howe, Richard, 1:65
- Howe, William, 1:242–243
- Howe truss, 1:242–243
- Hubble Space Telescope, 2:264; 3:278–279
- Hudson, Thomas, 1:54–55
- Hudson Canal Company, 1:245, 289
- Hudson Motor Car Company, 2:182
- Hudson River Rubber Company, 2:75
- Huggins, Charles Brenton, 3:261
- Hughes, Chris, 3:268
- Hughes, Howard, 3:42
- Hughes Aircraft, 3:2, 42
- Hull, Chuck, 3:316
- Hülsmeier, Christian, 2:309–310
- Human Genome Project, 3:279–380
- Human immunodeficiency virus (HIV). *See* AIDS research
- Humboldt, Alexander, von, 1:9, 46, 176
- Hungerford, David, 3:261
- Hunt, Walter
 breech-loading rifle designed by, 1:174, 284
 lockstitch sewing machine invented by, 1:170–171, 284,
 285
 Rocket Ball ammunition patented by, 1:281
 safety pin patented by, 1:285
- Hunter, John, 1:57
- Huntington, Collis, 1:275, 276, 290
- Huskey, Harry, 3:55
- Hyatt, Isaiah, 2:42–43
- Hyatt, John Wesley, 2:42–43
- Hybrid vehicles, 3:281–283
- Hydraulic fracturing (“fracking”), 3:66–67
- Hydroelectric power, 2:212–214
- Hydrogen bomb, 2:283
- Hydrogen energy, 3:67–68
- Hydroponics, 2:284–285
- Hypertext, 3:283
- Hypertext Markup Language (HTML), 3:165, 184, 208, 283,
 300
- Hypertext Transfer Protocol (HTTP), 3:165, 184, 208
- IBM 360 Computer, 3:17, 68–69
- IBM personal computer, 3:205–206
- Ice cream soda, 2:81–82
- In vitro fertilization (IVF), 3:70
- Indigo
 dyed jeans, 2:84–85
 experimentation of Lucas, Eliza, 1:3, 40, 41
 and slave labor, 1:71, 72
- Induction. *See* Electromagnetic induction
- Industrialism, Reconstruction, and the Gilded Age (1866–1900),
 2:1–7
 communication innovation, 2:7
 consumerism, 2:5–7
 defining issues, 2:1
 female entrepreneurship, 2:4–5
 industrialization of leisure, 2:5
 newspaper muckrakers, 2:2, 7, 172
 record number of patents, 2:1
 Reconstruction, 2:2–3
 public health and the modern city, 2:6–7
 Transcontinental Railroad, 2:3–4
- Infant formula, 3:206–207
- Inman, George (1895–1972), 2:82–83
- Insulin pump, 3:207–208
- Integrated circuit, 3:70–71, 76–77, 99–102, 132, 190, 192, 216
- Intel Corporation, 3:71–72
- Interchangeable gun parts, 1:243–244
- Interchangeable parts, 1:118–119
- Intercontinental ballistic missiles (ICBMs), 3:12, 239

- Minuteman I, 3:2
- R-7, 3:3
- Internal combustion engine, 1:119–121
 - development of, 2:119–121, 131–132, 181, 203
 - in hybrid vehicles, 3:281
 - steam engine replaced by, 1:149, 150
 - in submarines, 2:319
- International Ladies' Garment Workers' Union (ILGWU), 2:285–287
 - primary document: "The Uprising of the 20,000," 2:286–287
- International Space Station, 3:97, 105, 126–127, 166, 237–238, 283–285
- Internet, 3:208–209
 - ARPANET as forerunner to, 3:2–3, 16, 164, 190, 208, 300, 329
 - and Berners-Lee, Tim, 3:163, 165–166, 184–185
 - and net neutrality, 3:209
- Internet Explorer, 3:166, 190, 217, 301
- Internet Protocol (IP)
 - development of, 3:300
 - and early Internet, 3:17, 208
 - and 4G, 3:219
 - and packet switching, 3:17, 107
 - TCP/IP, 3:3, 107, 208, 300
- Interstate Highway System, 2:287–290
 - primary document: excerpt from the Federal-Aid Highway Act (1956), 2:289–290
- Intraocular contact lens, 3:285–286
- Inverted microscope, 1:244–245
- iPod, 3:286–287. *See also* Apple
- Iron ship with revolving turret, 2:83
- Iron- and silversmithing, 1:34–35
 - apprenticeships, 1:217
 - blacksmithing, 1:34–35
 - blacksmiths, 1:111, 163, 171, 209, 211, 217, 269; 2:156; 3:50
 - and cast-iron "Saugus pot," 1:54
 - in Colonial America, 1:3
 - and Conestoga tires, 1:209
 - and Deere, John, 1:171, 217, 269
 - definition of, 1:34
 - and Fitch, John, 1:111
 - and flexible catheter, 1:22
 - gunsmiths, 1:174, 202, 203, 281, 243–244; 2:80
 - and Michaux, Pierre, 2:156
 - and polished steel plow, 1:269
 - silversmiths, 1:22, 71, 111
 - and three-piece iron plow, 1:160
 - women as, 2:313–314
- Ironing board, 2:83
- Jackson, Andrew
 - and French and Indian Wars, 1:210
- Jacksonian democracy, 1:167
 - and Kentucky Rife in War of 1812, 1:35–36
 - and National Road, 1:134
 - and Panama Canal, 2:226
 - on Slater, Samuel, 1:147–148
 - urbanization and industrialization under, 1:235
- Jackson, Charles Thomas, 1:178
- Jackson, Janet, 3:323
- Jackson, Mary Winston (1921–2005), 3:72–74
 - biographical details, 3:72–73
 - career featured in *Hidden Figures* (film), 3:74
 - NASA's first black female engineer, 3:72, 73, 155
 - at West End Computers, 3:155
- Jackson, Michael, 2:118
- Jackson, Sandra Willett, 2:105
- Jackson, Thomas J. (Stonewall), 1:257
- Jackson, Thomas Penfield, 3:200, 301
- Jackson, Wes, 3:240
- Jacob, Mary Phelps (1891–1970), 2:214–215
- Janeway, Henry, 1:179
- Jarvik, Robert, 3:180
- Jarvik-7 artificial heart, 3:180
- Java, 3:287–290
 - primary document: interview with James Gosling, creator of Java (2001), 3:288–290
- Jeans, 2:84–86
- Jefferson, Thomas (1743–1826), 1:121–123
 - and agrarian versus manufacturing debate, 1:138, 139
 - American Philosophical Society member and president, 1:4, 8–9, 158
 - Dunbar and Freeman expedition ordered by, 1:4
 - federal banking system opposed by, 1:139
 - lap desk invented by, 1:4, 121, 122
 - Lewis and Clark Expedition ordered by, 1:4, 8, 45, 77, 123–125
 - moldboard plow invented by, 1:4, 122
 - Monticello, 1:122–123, 124, 141, 157–158, 162
 - and natural history, 1:4
 - and patent law, 1:135–137
 - primary document: excerpts from notes on wheel cipher, 1:163
 - Rush, Benjamin, eulogized by, 1:144
 - swivel chair invented by, 1:4, 157–158
 - wheel cipher invented by, 1:4, 162–163
- Jemison, Mae (1956–), 3:290–291
- Jencks, Joseph, 1:45, 54–55, 71, 76, 101, 136
- Jennings (Bartik), Betty Jean, 3:1, 56
- Jennings, Lewis, 1:281
- Jennings, Thomas L., 1:77
- Jervis, John B. (1795–1885), 1:245
- Jet Propulsion Laboratory (JPL), 3:74–75
 - Rocket Girls of JPL, 3:121–123
- Jobs, Steve (1955–2011), 3:80, 158, 163, 177–179, 209–213, 223, 244

- at Atari, 3:209, 244
- biographical details, 3:209–210
- and development of the iPhone, 3:212, 311–312
- and development of the iPod, 3:286
- NeXT, 3:178, 210, 213
- Pixar, 3:209, 210
- Jockstrap, 2:86
- Johnson, Andrew, 1:309
- Johnson, Clarence Kelly, 3:139–140
- Johnson, Edward H., 2:194–195
- Johnson, Eldridge, 2:29
- Johnson, Herbert, 1:222
- Johnson, Katherine Goble (1918–), 3:75–76, 155
- Johnson, “Lady Bird,” 2:289
- Johnson, Lyndon B., 2:105, 304
 - and Sentinel missile defense system, 3:239
 - War on Poverty, 3:106
- Johnson, Nancy M., 1:235
- Johnson, Willis, 1:222
- Johnson & Johnson, 1:175; 2:185; 3:196, 255
- Johnson Space Center, 3:105
- Joint United Nations Programme on AIDS (UNAIDS), 3:172–173
- Jones, Amanda T. (1835–1914), 2:86–87
 - primary document: “The Soldier’s Mother” by Amanda T. Jones (1867), 2:87
- Joystick/flight simulator, 3:291
- Kahn, Albert, 2:180
- Kahn, Robert, 3:3
- Kaposi’s sarcoma, 3:171, 173. *See also* AIDS research
- Kare, Susan (1954–), 3:213
- Keen, William W., 1:188
- Kellogg, William Keith (1860–1951), 2:88–89
- Kelly, Michael, 2:4
- Kelly, William (1811–1888), 2:89–90
- Kennedy, John F.
 - and Apollo Project, 3:14, 95
 - and Communications Satellite Act (1962), 3:42
 - and Operation Ranch Hand (Vietnam War herbicidal warfare program), 3:9
 - and Partial Test Ban Treaty (1963), 3:111
 - testing touch-tone phone at Seattle World’s Fair, 3:145
 - “Urgent National Needs” speech (1961), 3:4, 95
- Kennedy Space Center, 3:97, 237–238, 290
- Kenschaft, Patricia, 3:20
- Kentucky long rifle, 1:35–36
- Kettering, Charles F. (1876–1958), 2:204–205, 215–216, 219
- Kevlar. *See* Bulletproof vest/Kevlar
- Kier, Samuel (1813–1874), 2:90–91
- Kilby, Jack (1923–2005), 3:70–71, 76–77, 100, 215–216
- Kindle e-book reader, 3:251, 258, 265, 312
- Kinematoscope, 2:6, 59, 91, 103, 243
- Knight, Margaret (1838–1914), 2:91–92
- Know-Nothing Party, 1:171
- Knox, Rose Markward, 2:4
- Kolbe, Hermann, 2:18
- Kolff, Willem, 3:180
- Koop, C. Everett, 3:173–177
- Kurzweil, Ray (1948–), 3:291–292
- Kwolek, Stephanie Louise (1923–2014), 3:77–78
- Labor and labor unions
 - Amalgamated Clothing and Textile Workers Union (ACTWU), 2:15
 - Amalgamated Clothing Workers of America (ACWA), 2:14–16
 - American Federation of Labor (AFL), 2:15, 286
 - Baltimore Buttonhole Makers Union, 2:15
 - Chicago Men’s Garment Workers Strike, 2:14–15
 - child labor, 1:162, 298; 2:2, 7, 104–105
 - Congress of Industrial Organizations (CIO), 2:15
 - Factory Girls’ Association, 1:129
 - and Ford, Henry, 2:204
 - International Garment Workers of America, 2:4–5
 - International Ladies’ Garment Workers’ Union (ILGWU), 2:285–287
 - Lady Stitchers’ Union, 2:4, 92–93
 - Lowell Female Labor Reform Association (LFLRA), 1:129, 297–298
 - Operation Dixie (campaign to unionize Southern workers), 2:15
 - Ten-Hour Movement, 1:297–299
 - UNITE HERE, 2:15
 - United Garment Workers of America (UGW), 2:14–16
 - Workers United, 2:15
- Lackoff, Sam, 3:24
- Lacks, Henrietta (1920–1951), 3:78–79
- Lady Stitchers’ Union, 2:92–93
- Lam, Tat, 3:215
- Lamarr, Hedy (1914–2000), 2:290–292
 - primary document: patent for Hedy Lamarr’s Frequency-Hopping System (1942), 2:292
- Land mines, 1:245–246
- Land, Edwin H. (1909–1991), 3:79–80, 117–118
- Lange, Dorothea (1895–1965), 2:292–293
- Larson, John, 2:216–217
- Laser cataract surgery device, 3:213–214
- Lasers, 3:80
- Lavoisier, Antoine, 1:51
- Lawn mower, reel-type, 2:93
- LED lights, 3:81
- Lee, Linda, 3:121
- Lee, “Mother” Ann, 1:196
- Lend-Lease Program (1941–1945), 2:293–294
- Lennox, David (1855–1947), 2:93–94

- Leroux, Henri, 2:18
- Letterman, Jonathan, 1:187–188, 241
- Lewis, Alice Jackson, 1:201
- Lewis, Craig, 3:181
- Lewis, Meriwether, 1:8, 123–125. *See also* Lewis and Clark Expedition
- Lewis and Clark Expedition (1804–1806), 1:123–125
- American Philosophy Society sponsorship for, 1:124
 - artifacts housed in Peale Museum, 1:48
 - geographic and geological findings of, 1:125
 - and Jefferson, Thomas, 1:4, 8, 45, 77, 123–125
 - political goals of, 1:123
 - primary document: excerpts from expedition journal (1805, 1806), 1:126–127
 - Sacagawea as guide to and voting member of, 1:23, 125
 - scientific goals of, 1:123–124
 - scientific observations and discoveries of, 1:124–125
 - social science contribution of, 1:125
 - York (African American slave) as voting member of, 1:125
- Li, Min Chiu, 2:261
- Liberty Ships, 2:294–295
- Lichterman (Teitelbaum), Ruth, 3:1, 56
- Lie detector, 2:216–217
- Life Savers candy, 2:217
- Lightning rod, 1:36–37
- primary document: frontispiece and title page of Benjamin Franklin's *Experiments and Observations on Electricity* (1774), 1:37
- Lilienthal, Otto, 2:165, 176
- Lincoln, Abraham, 1:138, 167, 285, 308–309
- assassination of, 1:273
 - and construction of U.S. Capitol, 1:305
 - first transcontinental telegraph wire received by, 1:296
 - floating dry dock patented by, 1:113–114, 228–230
 - and Pacific Railway Act (1862), 1:258
 - primary document: excerpt from patent application for floating dry dock (1849), 1:229–230
 - and steam locomotive, 1:288–290
 - and telegraph, 1:257, 296, 310–311
- Lindbergh, Charles, 2:175, 178, 190
- Ling, Helen, 3:121–122
- Linotype machine, 2:94–95
- Linux, 3:221, 292–293
- Liotta, Domingo, 3:181
- Lipman, Hymen, 1:267
- Liquified natural gas (LNG) carrier, 3:82
- Liskov, Barbara (1939–), 3:82–83
- Literacy
- reading, 1:33, 169, 171, 191; 2:54, 285; 3:201, 295
 - technology, 3:177, 256
- Lobster trap, 1:127
- Lockheed Martin, 2:178
- primary contractor for Terminal High Altitude Area Defense (THAAD), 3:12
 - space shuttle external tank constructed by, 3:237
 - stealth technology developed by, 3:139–140
- Long, Crawford Williamson (1815–1878), 1:178, 246–247
- biographical details, 1:246–247
 - pioneer of use of sulfuric ether for anesthesia, 1:178, 246–247
- Long arm. *See* Extension arm
- Loom, 1:38–40
- primary document: excerpts from diary of Martha Ballard describing home weaving (1787), 1:39–40
- Loughead, Malcolm, 2:182
- Love, Nancy Harkness, 2:261, 331–332
- Love, William, 2:108
- Love Canal, 2:108
- Lovelace, William Randolph, II, 3:88
- Lowell, Francis Cabot, 1:5, 74, 128, 161–162
- Lowell mill system, 1:5, 61, 74, 128–130, 161–162
- Factory Girls' Association, 1:129
 - Lowell Female Labor Reform Association (LFLRA), 1:129, 297–298
 - primary document: description of the life of a mill girl (1845), 1:129–130
 - Ten-Hour Movement, 1:297–299
- Lucas, Eliza (1722–1793), 1:40–42, 45
- indigo experimentation of, 1:3, 40, 41
 - primary document: letter of Eliza Lucas to her father (1741), 1:41–42
- Lucas, George
- Skywalker Ranch, 3:134–135
 - Strategic Defense Initiative named after *Star Wars*, 3:239
- Lyceum Movement, 1:168
- Lyman, William Worcester, 2:4, 33–34
- M&M's, 2:295, 300
- M4 Sherman Tank, 2:295–296
- M16 Rifle, 3:83–84
- MacDonald, Thomas, 2:257, 287
- Machine/Gatling gun, 1:247–249
- Macintosh, Charles, 3:115–116
- Madison, James, 1:87
- and canal building, 1:6
 - First Bank allowed to expire under, 1:139
 - on intellectual property law, 1:136
 - on tariffs, 1:138
- Magnetic resonance imaging (MRI), 3:84–85
- Maher, Mary Denis, 1:191
- Maker Faire, 3:254, 293–295
- Manhattan Project, 2:201, 260, 264, 272, 296–297; 3:60–61, 111, 220
- and Calutron Girls, 2:267–268
 - and Oppenheimer, J. Robert, 2:303–304
 - and Wu, Chein-Shiung, 2:333–334
- Manifest destiny, 1:78, 171
- Mann, Horace, 1:169

- March for Science, 3:295
- Marconi, Guglielmo, 2:5, 171, 236
- Marcus, Siegfried, 2:181
- Margarine, 2:95
- Markkula, Mike, 3:177
- Mars Rover Series, 3:295–297
- Marsh, Albert L. (1877–1944), 2:217–218
- MASER, 3:85
- Masking tape, 1:175; 2:113, 218, 241. *See also* Adhesive tape
- Mason, John Landis
 mason jar invented by, 1:173–174, 249
 salt shaker invented by, 1:267
- Mason jar, 1:173–174, 249
- Masters, Sybilla (c. 1675–1720), 1:42
- Matchbook matches, 2:96
- Mather, Cotton (1663–1728), 1:43–44
- Matulka, B. Rebecca, 3:50–53
- Matzeliger, Jan Ernst (1852–1889), 2:4, 96–97
- Mauchly, John, 3:55, 150–151
- Maxim, Hiram, 1:247–249
- Maxim, Hudson (1853–1927), 2:97
- Maynard, Edward (1813–1891), 1:249–250
- Maynard carbine, 1:250–252
- McClintock, Barbara (1902–1992), 3:86–87
- McCormick, Cyrus (1809–1884), 1:252–254
 primary document: letter from Robert E. Lee regarding
 curriculum at Washington College (1865), 1:253–254
- McCormick, Katherine, 3:31
- McKnight, William L. (1887–1978), 2:218–219
- McLuhan, Marshall, 1:168
- McNeill, Thomas E., 1:222
- McNulty (Mauchly Antonelli), Kathleen “Kay,” 3:1, 56
- Mead, Margaret (1901–1978), 2:297–299
- Mechanical reaper, 1:254–255
- Mercury 13, 3:88
- Merlin, John Joseph, 1:282
- Merrick, Solymon (1806–1852), 1:255
- Metal detector, 2:97–98
- Metal electrode weld, 2:98–99
- Metal windmill, 2:99–100
- Metcalf, Robert (1946–), 3:214–215
 American Arithmometer Company financed by, 2:14
 coinventor of Ethernet, 3:215
 Metcalf’s Law, 3:214
 3Com founded by, 3:215
- Microchip, 3:215–217
- Microsoft, 3:217–218
 competition with Intel, 3:72
 competition with Linux, 3:293
 Internet Explorer, 3:166, 190, 217, 301
 MS-DOS, 3:200, 206, 211, 217
 Windows, 3:166, 200, 211, 217–218, 251–253, 286, 301
 See also Gates, Bill
- Microwave oven, 2:299
- Midgley, Thomas (1889–1944), 2:204–205, 219–220; 3:38
- MIDI (Musical Instrument Digital Interface), 3:297
- Miescher, Friedrich, 3:4, 202
- Military-industrial complex, 3:88–90
 and “big science,” 2:264
- Military technology (Civil War), 1:255–258
 amputations, 1:256
 medical history, 1:256
 photographic documentation, 1:256
 railroad’s impact, 1:257–258
 sanitation, 1:256
 submarines, 1:257
 surgery, 1:256
 systems, 1:256
 telegraph’s impact, 1:256–257
 weaponry, 1:256
- Military technology (post–Civil War through World War I),
 2:100–102
 air balloons, 2:101
 aircraft in WWI, 2:75, 171, 176, 178, 234; 3:48
 machine guns, 2:102
 medical technology, 2:102
 minié bullets, 2:101
 railroad’s impact, 2:101
 submarines, 2:101
 tanks, 2:101
 telegraph’s impact, 2:102
- Military technology (World War II), 2:299–301
 aircraft, 2:189, 223, 234, 255–256, 261–262, 300, 301; 3:7
 ammunition, 2:300
 atomic bombs, 2:300 (*see also* Atomic bombs/nuclear
 weapons)
 DDT, 2:301
 food and nutrition, 2:300
 health and medicine, 2: 300–301
 nylon, 2:301
 radar, 2:300, 301–302, 310, 320
 sonar, 2:300
- Miller, Phineas, 1:99–100, 117, 164, 165
- Miller, Samuel, 1:84
- Milliken, Greg, 3:168
- Milling machine, 1:130–131
- Minuteman I (ICBM), 3:2
- Minsky, Marvin (1927–2016), 3:90–91
- MIT Radiation Laboratory, 2:301–302
- Mitchell, Maria (1818–1889), 1:19, 258–259
- Mobile phone, 3:218–219
- Molina, Mario J., 2:176; 3:38
- Moll, Gerard, 1:199
- Monroe, James, 1:260
- Monroe, Rose Will, 2:314
- Monroe Doctrine, 1:168

- Monsanto, 2:136; 3:9, 19, 172, 273
 Montagnier, Luc, 3:172, 175
 Montague, Hannah Lord, 1:219–220
 Monte Carlo method (computer algorithms), 3:56, 289
 Montgolfier brothers, 2:176
 Moody, Paul, 1:74
 Moog, Robert (1934–2005), 3:91–92
 Moore, Ann (1934–), 3:298
 Moore, Gordon, 3:71–72, 100, 101, 131, 217
 Moore, Hiram, 1:171, 205
 Moore, John Hamilton, 1:137
 Moore's Law, 3:71, 132, 133, 217, 289
 Morey, Samuel (1762–1843), 1:76, 131–132, 148
 Morgan, Garrett (1877–1963), 2:220–221
 Morgan, J. Pierpont, 2:2, 35, 36–37, 58, 61, 74, 107, 160, 169, 324
 Morgan, Mary Sherman (1921–2004), 3:92–93
 Morphine, 2:59
 as anesthesia, 1:179, 187
 discovery of, 1:178
 wartime use of, 1:187
 Morrison, William J.
 cotton candy invented by, 2:45
 first electric car designed by, 3:49, 50, 247
 Morse, Samuel F. B. (1791–1872), 1:78, 260–261; 2:120
 biographical details, 1:260
 correspondence with Mitchell, Marie, 1:259
 and Henry, Joseph, 1:237
 inspired by Humboldt, Alexander von, 1:46
 and telegraph line/cable, 1:202, 226, 260, 261–262, 295
 telegraph invented by, 1:7, 226, 256, 260, 261–262, 236
 See also Morse code
 Morse code, 1:7, 169, 257, 260, 261–262, 295; 2:236, 323; 3:25, 328
 Motion picture camera, 2:102–104
 Motorcycle (pre–World War II), 2:221–222
 Motorcycles, 1:120, 121; 3:36
 Motorola, 2:182, 205–206
 MP3, 3:298–299
 Muller, Paul Hermann, 3:6
 Multitubular boiler, 1:132
 Mural, Frank, 3:55

 Nanotechnology, 3:93–94
 Napalm, 3:94
 Nash-Kelvinator Corporation, 2:182
 National Academy of Sciences (NAS), 1:262–263
 National Advisory Committee for Aeronautics (NACA), 2:223
 National Aeronautics and Space Administration (NASA), 3:94–98
 centers and facilities, 3:97
 creation of, 3:94–95
 primary document: letter of Dwight Eisenhower to Keith Glennan (1960), 3:98
 Project Mercury, 3:88, 95, 96
 Skylab, 3:97, 133–134, 284
 and space science, 3:96
 Terra, 3:96–97
 See also Apollo Project; International Space Station; Space shuttle program; Voyager spacecraft
 National Consumers League, 2:104–105
 National Institutes of Health (NIH), 2:6, 105–106; 3:98, 119
 AIDS research, 2:105; 3:173, 175
 artificial heart program, 3:180
 Human Genome Project funded by, 3:279–280
 Rocky Mountain Labs, 2:240
 National Oceanic and Atmospheric Administration (NOAA), 1:78; 3:144
 National Road, 1:132–134
 National Science Foundation (NSF), 3:98–99
 Nativism, 1:171
 Natural history, 1:44–46
 Natural philosophy, 1:4, 8–9, 31, 44, 237
 Needham, Orwell H., 1:182
 Negroponte, Nicholas (1943–), 3:299–300
 Neoprene, 2:302–303
 Netscape, 3:166, 190, 256, 274, 300–301
 New Deal, 2:213, 251–257
 and Ford, Henry, 2:204
 and Lange, Dorothea, 2:292–293
 Tennessee Valley Authority Electricity Project (TVA), 2:213, 251–252, 328–329
 union support for, 2:286
 Works Progress Administration, 2:213
 See also Hoover Dam
 New Millennium (2000–present), 3:247–254
 alternative energy sources, 3:247–248
 bioprinting, 3:248
 electric cars, 3:247
 laser technology, 3:248
 medical technology, 3:249–250
 open-source software, 2:252
 portable technology, 2:253–254
 search engine technology, 2:252–253
 technology in education, 3:250–251
 technology in music, 3:251–252
 3-D technology, 3:248–249
 New Republic and the Market Economy (1780–1820), 1:71–79
 African technologies, 1:71
 agricultural innovation, 1:73–74
 amateur scientists, 1:77–78
 attitudes toward science, 1:71–72
 Census Act (1790), 1:73
 factory system, 1:74
 immigration's significance, 1:71–72, 74, 76–77

- interchangeable parts, 1:75–76
- medical sciences, 1:75
- shipbuilding, 1:73
- steam power, 1:76–77
- transportation engineering, 1:75–76
- Newbold, Charles, 1:73, 159
- Newton, Isaac, 1:27, 33, 68, 103, 144
- Niagara Falls Power Plant, 2:106–112
 - primary document: excerpt from Nikola Tesla’s commemoration address (1897), 2:108–112
- Niépce, Joseph Nicéphore, 2:31–32
- Nightingale, Florence, 1:88, 89, 187, 256, 263–264, 307
- Nightingale Plan, 1:263–264, 307
- 911 emergency system, 3:8–9
- Noether, Amalie Emmy (1882–1935), 2:224–225
- North, Simeon (1765–1852), 1:76, 243, 264–265
- Nowell, Peter, 3:261
- Noyce, Robert (1927–1990), 3:71–72, 77, 99–102, 131, 215–216
 - primary document: personal interview for the IEEE History Center (1975), 3:100–102
- Nuclear and radiation accidents, 3:102–104
- Nuclear energy/nuclear power plants, 3:219–221
- Nuclear weapons. *See* Atomic bombs/nuclear weapons
- Nye, Bill (1955–), 3:302
- Nystatin, 3:5, 13–14. *See also* Antibiotic

- Obama, Barack, 3:34, 41, 53, 76, 226
 - and Keystone XL pipeline, 3:114
 - napalm ban signed by, 3:94
 - One Maker Faire hosted by, 3:294
- Obama, Michelle, 3:291
- Obsolescence, 2:207; 3:22, 163, 168
- Ochoa, Ellen (1958–), 3:105–106
- Odometer, 1:135
- Office technology (pre–World War II), 2:112–114
- Olds, Ransom Eli (1864–1950), 2:225
- Olmsted, Frederick Law, 2:6, 162, 167, 174
- Olson, Richard, 3:255
- Omnibus System, 1:265–266
- One Laptop per Child, 3:302–303
- Onesimus (fl. 1706–1716), 1:46–47
- oN-Line System (NLS), 3:3
- Onion Router. *See* TOR (The Onion Router)
- Open-source software, 3:221–222
- Oppenheimer, J. Robert (1904–1967), 2:272, 296–297, 303–304, 316; 3:111
- Orshansky, Mollie (1915–2006), 3:106–107
- Orwell, George, 3:169–170, 210
- O’Sullivan, John L., 1:171
- Otis, Elisha Graves, 1:224–225, 256–257; 2:139, 162, 201
- Otis, William, 1:168, 291–292
- Otis Elevator Company, 1:224–225, 256–257; 2:65–66
- Owens, Michael, 2:190–191

- Pacific Railroad Act, 1:276–279; 2:3, 153
- Pacific Telegraph Act (1860), 1:7, 296
- Packet switching, 3:107–108
- Packing tape, 1:175. *See also* Adhesive tape
- Paine, Thomas, 1:76
- Panama Canal, 2:143, 163, 172, 225–232, 279
 - primary document: excerpt from Theodore Roosevelt’s message to Congress after Returning from Canal Zone (1906), 2:228–232
- Paper bag, 2:114
- Paper clip, 2:114–115
- Papermaking machine, 1:266
- Parmly, Levi Spear, 1:75, 102
- Particle accelerator, 3:108–110
 - primary document: press release issued by CERN, the European Organization for Nuclear Research (2012), 3:109–110
- Pascal, Blaise, 1:265
- Patent and copyright statutes, 1:135–137
 - Copyright Act (1790), 1:136
 - and music, 3:298
 - Patent Act (1790), 1:136
 - Patent Act (1836), 1:170
- Paul, Les (1915–2009), 2:270–271, 304–305
- Pauling, Linus “Carl” (1901–1994), 3:34, 110–111
- PayPal, 3:303–304
- Peabody, Elizabeth Palmer, 1:168, 170, 259
- Peale, Charles Willson (1741–1827), 1:47–51
 - primary document: letter to Thomas Jefferson regarding agricultural innovations (1815), 1:48–51
- Pemberton, John “Doc,” 2:43–44
- Pencil eraser, 1:267
- Penicillin, 2:6, 256–257, 300–301, 306–307; 3:5, 13
- Penn, Sean, 3:134–135
- Penn, William
 - Charter of Privileges (1701), 1:10
 - Governor’s Mill built for, 1:42
 - scientific legacy of, 1:72
- Pennington, Mary Engle (1872–1952), 2:232
- Pepper (and salt) shaker, 1:267
- Perkins, Jacob (1766–1849), 1:76, 161, 267–268
- Perkins, William C., 1:234
- Perlman, Radia (1951–), 3:222–223
- Permanent press fabric, 3:111–112
- Personal computer (PC), 3:223–224
- Petroleum industry (post–World War II), 3:112–114
- Petroleum industry (pre–World War II), 2:233–234
- PGP Encryption, 3:303–304
- pH Meter, 2:307–308
- Phelps, George M., 1:272

- Phonograph, 2:115–119, 208–210
 and Bell, Alexander Graham, 2:117, 209
 invented by Edison, Thomas, 2:115–118, 208–210
 primary document: roll call of companies at the
 Phonograph Convention in Chicago (1890), 2:119
- Photocopier, 2:307–308
- Photographic film, 2:120–121
- Photography. *See* Camera
- Pierce, William, 1:11
- Pinball and arcade games, 2:308–309
- Pinckney, Eliza Lucas. *See* Lucas, Eliza
- Pincus, Gregory, 3:31
- Pipe wrench, 2:121
- Piria, Raefele, 2:18
- Pixii, Hippolyte, 2:9
- Plasma arc welding, 3:114–115
- Plastic wrap, 2:256, 301, 309
- Plastics, 3:115–117
- Platform scale, 1:168, 268–269
- Player piano, 1:121–122
- Pneumocystis carinii pneumonia (PCP), 3:171, 173. *See also*
 AIDS research
- Polaroids, 3:79–80, 117–118
- Polio vaccine, 3:54, 118–119, 124, 125–126, 152
- Polished steel plow, 1:269
- Pong, 3:20–22, 119–120, 321, 325
- Poplawski, Stephen J., 2:189
- Pop-up toaster, 2:234–235
- Portable transistor radio, 3:120–121
- Portland cement mortar, 2:122–123
- Post-Cold War Era (1980–1999), 3:163–170
 ARPANET and Internet, 3:164–165
 cloning, 3:166
 computer browsers, 3:166
 computers, 3:165–166
 consumer electronics, 3:166–167
 consumerism and choice, 3:163–167
 entertainment advances, 3:167
 hacking, 3:168
 journalism and information transmission, 3:168
 mobile phones, 3:167
 myth of “millennium meltdown” (Y2K), 3:169
 myth of “paperless office,” 3:168–169
 obsolescence, 3:163, 168
 and Orwell, George, 3:169–170
 rate of technological innovation, 3:163
 smart car technology, 3:167–168
 and Soviet Union, 3:163–164
- Practical ocean navigation, 1:137–138
- Priestley, Joseph (1733–1804), 1:51–52
 biographical details, 1:51
 carbonated water created by, 1:51; 2:141
 influence on study of ecology, 1:51
 nitrous oxide experiments, 1:178
 oxygen discovered by, 1:51
- Printing, 1:269–271
 electric typewriters, 2:173; 3:61–62, 69
 first printing press in America, 1:32–33
 Gutenberg’s printing press, 1:270–271
 history of, 1:270–271
 Jefferson’s portable printing press, 1:122
 laser printing, 1:271; 3:159, 249
 Linotype machine, 2:94–95
 movable type, 1:270
 photocopying, 2:307; 3:158–160, 168
 QWERTY keyboard, 2:155–156
 rotary printing press, 1:169, 174
 typewriter, 1:271; 2:5, 155–156
 woodblock printing, 1:270
 See also 3-D printing
- Printing telegraph, 1:169, 271–272, 310
- Progressive Era and the Roaring Twenties (1900–1929),
 2:169–175
 automobile advances, 2:169–170
 communications and media advances, 2:171
 daily life advances, 1:172–173
 film and photography, 2:171
 health-related advances, 2:175
 medical and health advances, 2:172–173, 175
 Panama Canal, 2:172
 Taylorism, 2:146–147, 170, 208
 technological challenges of urbanization, 2:173–175
 transportation advances, 2:169–170
 and wealth, 2:171–172
 Wright brothers’ inaugural airplane flight, 2:170–171
- Pullman, George Mortimer (1831–1897), 1:273, 290
- Pullman car. *See* Railroad sleeping car
- Punch card tabulator, 2:123
- Pure Food and Drug Act (1906), 3:18
- Puritanism, 1:2, 12, 43, 72, 85–86
- Pushpin, 2:113, 235–236
- Putting-out production system, 1:4, 5
- Quadruplex telegraph, 2:124–125
- Quakerism, 1:13, 42, 44–45, 72, 101, 201
- Quantum science, 3:304–305
- Queeney, John Francis, 2:136
- Quinby, Moses, 1:24
 primary source: excerpt from *Mysteries of Bee-Keeping Explained* on use of bee smoker, 2:24–25
- QWERTY layout. *See* Typewriter and QWERTY
- Radar, 2:309–310
- Radio, 2:236–240
 primary document: “Radio’s Real Uses” by E. E. Free,
 science editor for *The Forum* (1926), 2:239–240

- Radioplane Company, 3:48
- Railroad refrigerator car, 2:125–126
- Railroad sleeping car and Pullman car, 2:126–127
- Railroad switch systems, 2:127–128
- Railroad T-rail and tie, 1:168, 273–274, 293
- Railroads, 1:274–279
- Pacific Railway Act (1862), 1:258
 - primary document: Pacific Railway Act (1862), 1:276–279
 - Transcontinental Railroad, 1:208–209, 258, 275, 288–289, 296; 2:3, 153–155
 - and war, 1:257–258, 275; 2:101
- Rains, Gabriel, 1:245–246
- Ratchet wrench, 1:279–280
- Reagan, Ronald, 3:59, 89–90, 100, 173–175, 245
- and International Space Station, 3:280
 - and Strategic Defense Initiative (SDI or “Star Wars”), 3:12, 90, 239–240
- Reed, Ezekiel, 1:76
- Refrigerator, 2:310–311
- Relay, 1:280
- Remington Rand, Inc., 3:1, 151, 189
- Repeating rifle, 1:280–282
- Report on Manufactures* (1791), 1:72, 138–139, 284
- RFID labels, 3:305–307
- Richards, Ellen Swallow (1842–1911), 2:128–129
- Richardson, J. J., 1:280
- Richter scale, 2:311
- Rickover, Hyman, 3:128–129
- Ride, Sally (1951–2012), 3:224–226
- Ritchie, Dennis (1941–2011), 3:226–229, 313–316
- primary document: abstract for “The Development of the C Language” by Dennis Ritchie (1993), 3:227–229
- Rittenhouse, David (1732–1796), 1:8, 28, 52–54, 45, 73, 137
- biographical details, 1:52
 - diffraction grating created by, 1:52, 103–104
 - primary document: letter from Thomas Jefferson (1778), 1:53–54
- Ritty, James, 2:42
- River steamer, 1:139–140
- RNA (ribonucleic acid), 3:4
- Robber barons, 1:276; 2:34
- Robbins, Frederick C., 3:4, 54
- Roberts, Macie, 3:121
- Roberts, Nathan, 1:76
- Robotic surgery, 3:229–232
- primary document: letter from Acting District Director of the FDA to President of Intuitive Surgical Inc. on the regulation of robotic surgery (2013), 3:230–232
- Rock, Arthur, 3:71
- Rock, John, 3:31–32
- Rockefeller, John D., 2:2, 160
- Rocket Girls of JPL, 3:121–123
- primary document: press release announcing Eleanor F. Helin’s naming to WITI Hall of Fame (1998), 3:122–123
- Rocketry (pre–Space Age), 2:311–313
- Rocky Mountain Laboratories, 2:240
- Roebbling, Emily (1843–1903), 2:129–133
- biographical details, 2:129
 - primary document: photograph of promenade on Brooklyn Bridge, 2:131
 - role in construction of Brooklyn Bridge, 2:30, 129–131, 132
- Roebbling, John (1806–1869), 2:30–31, 131–132
- biographical details, 2:131
 - designer of Brooklyn Bridge, 2:131–132
- Roebbling, Washington A., 2:30, 130, 132
- Rogallo, Francis Melvin (1912–2009), 3:123–124
- Rohwedder, Otto Frederick, 2:191
- Roll film, 2:133
- Roller coaster, 2:133–134
- Roller skates, 1:282–283
- Roosevelt, Eleanor, 2:104, 331
- Roosevelt, Franklin D.
- as assistant secretary of the navy, 2:223
 - and Carver, George Washington, 2:40
 - and Einstein, Albert, 2:201, 260, 272
 - Executive Order 8802 (prohibiting racial discrimination in the national defense industry), 3:154
 - and England’s Tizard Mission, 3:331
 - first American president to appear on television, 2:163
 - fireside chats, 2:237, 254
 - and Ford, Henry, 2:204
 - and Hoover Dam, 2:279, 280–283
 - and interstate highway system, 2:287
 - and Lend-Lease Act, 2:293–294
 - and Manhattan Project, 2:202, 260, 272, 296
 - and MIT Radiation Laboratory, 2:301–302
 - and National Cancer Act (1937), 3:261
 - primary document: Hoover Dam dedication speech, 2:280–283
 - Rural Electrification Administration (REA) created by, 2:252
 - shift from “Dr. New Deal” to “Dr. Win the War,” 2:256
 - and Tennessee Valley Authority Electricity Project (TVA), 2:328
 - See also* New Deal
- Roosevelt, Nicholas, 1:76–77, 293
- Roosevelt, Theodore
- Bureau of Reclamation established under, 2:277–278
 - as first modern president, 2:7
 - and military-industrial complex, 3:89
 - New Nationalism of, 2:172
 - opposition to ban on saccharine by, 2:136; 3:18
 - and Panama Canal, 2:227–232
 - primary document: excerpt from message to Congress after returning from Panama Canal Zone, 2:228–232
 - and Reclamation Act (1902), 2:278
- Root, Elisha K., 1:202–203, 204
- Ropes, Hannah, 1:190
- Rosie the Riveter, 2:313–316

- primary document: excerpt from interview with Maria Isabel Solis (2003), 2:315–316
- Rotary hook (for sewing machines), 1:283
- Rotary washing machine, 2:134–135
- Rothem, Erik, 2:176
- Rous, Francis Peyton, 3:261
- Rowing machine, 2:135
- Rowland, Frank Sherwood, 2:176; 3:38
- RU-486/Plan B, 3:307–308
- Rucker ambulance, 1:283–284
- Rudy, Marion Frank, 3:11
- Ruggles, John, 1:170
- Rumford Fireplace, 1:141, 158–159
- Rumsfeld, Donald, 3:19
- Rush, Benjamin (1746–1813), 1:142–145
primary document: excerpt from medical writings of Benjamin Rush (1805), 144
- Sabin, Albert B. (1906–1993), 3:54, 119, 124–125
- Saccharine, 2:135–137; 3:18
controversy and regulation, 2:136–137
and Roosevelt, Theodore, 2:136; 3:18
Sweet’ n Low (brand name), 2:137, 3:18
- Safety pin, 1:284
- Safety razor, 2:240–241
- Salicylic acid. *See* Aspirin
- Salk, Jonas (1914–1995), 3:54, 119, 124, 125–126, 152
- Salt shaker. *See* Pepper (and salt) shaker
- Sänger, Eugen, 3:237
- Sanger, Larry, 3:250
- Sanger, Margaret, 3:31
- Saquinavir, 3:172. *See also* AIDS research
- Sarnoff, David, 2:171
- Satellite radio, 3:232–233
- Satellites and space probes, 3:126–127
- “Saugus pot,” 1:54–55
- Scheele, Carl Wilhelm, 1:51
- Schenck, John F., 1:78
- Schlatter, John, 3:18
- Schooner, 1:55–56
- Schultz, Jane E., 1:190–191
- Schwinger, Julian (1918–1994), 2:316–317
- Science Friday*, 3:308
- Scientific management (Taylorism), 2:146–147, 170, 208
- Scotch Tape, 2:113, 218, 241. *See also* Adhesive tape
- Scott, Charlotte, 3:20
- Scott, Ewin, 2:134
- Scott, Mike, 3:177
- Scott, Richard, 2:330
- Scott, Thomas, 2:34
- Scott, Walter, 2:47–48
- Scott, Winfield, 1:213
- Screw-cutting lathe, 1:145
- Sculley, John, 3:177–178
- Seaborg, Glenn, 2:260
- Self-driving cars, 3:233
- Selfridge, Thomas, 2:178
- SEMATECH, 3:234–235
- Simple, Ellen Churchill (1863–1932), 2:317–318
- Sertürner, Friedrich, 1:178
- SETI (Search for Extraterrestrial Intelligence), 3:308–311
- Seward, William, 1:10
- Sewell, William, 3:180
- Sewing machine, automated, 1:284–286
- Sewing pattern, 1:286–287
- Shapiro, Bob, 3:19
- Sharecropping, 2:3
- Sharpless, Thomas Kite, 3:55
- Shaw, Robert F., 3:55
- Shepard, Alan, 3:4, 88
- Sherman, Patsy O’Connell (1930–2008), 3:127–128
- Shippingport Atomic Power Station, 3:128–129
- Shockley, William, 3:1, 131, 148
- Sikorsky, Ivan, 2:276–277
- Silent Spring* (1962), 2:288–289; 3:6–7, 18, 36–38, 129–130.
See also Carson, Rachel (1907–1964)
- Silicon Valley, 3:130–132
- Silo, 2:137–138
- Silver, Bernard, 3:25
- Silverman, Jacob, 3:93
- Simms, Frederick, 2:183
- Singer, E. C., 1:288
- Singer, Isaac
first commercially viable sewing machine developed by, 1:6, 285–286
marketing skills of, 1:285
patent battle with Howe, Elias, 1:6, 285
- Singer Sewing Machine Company, 1:285, 303; 3:25
- Single-chip microprocessor, 3:132–133
- Skylab, 3:97, 133–134, 284
- Skyscraper, 2:138–140
- Skywalker Ranch, 3:134–135
- Slater, Hannah Wilkinson (1775–1812)
Almy, Brown, & Slater, 1:101
first woman to receive U.S. patent (two-ply cotton thread), 1:5, 74, 101
Quaker background of, 1:45, 101
- Slater, Samuel (1768–1835), 1:5, 45, 146–148
Almy, Brown, & Slater, 1:101, 147
biographical details, 1:146
carding machine created by, 1:146
first U.S. cotton spinning mill (Pawtucket, Rhode Island), 1:101, 146–147, 148
hydropowered yarn-spinning factories, 1:74, 101, 147
Samuel Slater and Company, 1:147
Slater mill system (also Rhode Island system), 1:61, 74, 101, 146–147, 161
Slaterville, Rhode Island, founded by, 1:5

- water frame spinning machine created by, 1:146
and workforce and labor conditions, 1:147
- Smallpox, eradication of, 3:135–136
- Smallpox inoculation, 1:56–59
primary document: George Washington's order for soldiers to receive inoculation (1778), 1:58
primary document: letter of Edward Rowse to Thomas Jefferson suggesting possibility of vaccines for other diseases (1805), 1:58–59
- Smartphone and 3G network, 3:311–312
- Smith, Adam, 1:138; 2:179, 180
- Smith, Al, 2:51, 239
- Smith, Andrew, 2:77
- Smith, C. Harold, 2:45–46, 186–187
- Smith, Dave (engineer and synthesizer designer), 3:297
- Smith, David M. (modern clothespin patent), 1:196
- Smith, Francis Pettit, 1:293
- Smith, Fred, 2:225
- Smith, Hamilton (genetic researcher), 3:203
- Smith, Hamilton (inventor of rudimentary rotary washing machine), 2:134
- Smith, Horace, 1:281
- Smith, John Lawrence, 1:244
- Smith, Lucien, 2:20
- Smith, Richard, 2:263
- Smith, Roe, 1:131
- Smith, Sam (co-inventor of Scotchgard Fabric Protector), 3:127
- Smith, Samuel (copper tycoon), 2:225
- Smith & Wesson Company, 1:281
- Smithing. *See* Goldsmiths; Iron- and silversmithing
- Smithsonian Institution
gum with bar code at, 3:25
and Henry, Joseph, 1:7, 237–238
original UNIVAC at, 3:151
space shuttles at, 3:238
and Wright brothers, 2:165, 177
- Smoke detector, 3:136–137
primary document: Chris P. Borreson's account of the Iroquois Theater Fire (1904), 1:137
- Snyder (Holberton), Frances "Betty," 3:1, 56
- Soda fountain, 2:140–141
- Solar compass, 1:287. *See also* Equatorial sextant
- Solar energy, 3:235–237
- SONAR, 2:318–319
- Sorensen, Charles Emil, 2:179–180
- Sorensen, Edward M., 3:48
- Space science and technology, 3:137
primary document: account of astronaut David Alexander Wolf voting in space (1997), 3:138
- Space shuttle, 3:96, 237–239
- Spar torpedo, 1:288
- Species extinction, 1:47, 175, 176; 3:250
- Spindler, Michael, 3:178
- Spinning wheel, 1:59–61
primary document: "Address to the Ladies" urging American women to boycott British goods (1767), 1:61
- Spirit of St. Louis*, 2:175, 178, 190
- Spork, 2:141–142
- Sprague, Frank Julian, 2:5, 242
- Sputnik 1, 2:313; 3:2–3, 14, 16, 89–90, 93, 94–95, 126, 284
- Sputnik 2, 3:3, 93, 126
- Standard Oil, 2:2, 233–234
- Stanford, Leland, 1:275, 276, 290
- Stanley, William, Jr., 2:9–10
closed core transformer perfected by, 2:9, 64
and Great Barrington Electrification, 2:9, 62
primary document: AIEE member biography for, 2:10
Stanley Manufacturing Company founded by, 2:9
at Westinghouse Electric Company, 2:9, 64
- Stanley Home Products, 3:157
- Stanley Motor Carriage Company, 1:148
- Stealth technologies, 3:138–140
- Steam engine, 1:148–149
patent of Watt, James, 1:107, 148, 151, 167, 289, 293
- Steam locomotive, 1:288–291
Best Friend steam engine, 1:181
- Steam shovel, 1:291–292
- Steam tractor, 1:149–150
- Steamboat, 1:150–154
primary document: newspaper announcement of Fulton's steamboat (1807), 1:153–154
primary document: Dickens's account of ride on steamboat (1842), 1:154
- Steel arched bridge, 2:142–143
- Stephenson, John, 1:239, 265
- Stethoscope, binaural, 2:143–144
- Stetson. *See* Cowboy hat (Stetson)
- Stevens, Edwin, 1:274, 293–294
- Stevens, John, 1:274, 292–293
- Stevens, Robert Livingston (1787–1856), 1:292–294
biographical details, 1:292–293
first U.S. locomotive built by, 1:293
railroad T-rail designed by, 1:168, 274, 293
steamship and steam ferry designs of, 1:76, 115, 274, 293
- Stewart, Philo Penfield, 1:207–208
- Stockyards, 2:144–145
primary document: photograph of Chicago's Union Stock Yards (1907), 2:145
- Stoddard, Joshua, 1:183–185
- Stone, Edward, 2:18
- Stoneman, George, 1:185
- Stoner, Eugene, 3:83, 84
- Stowe, Harriet Beecher, 1:170
- Strassman, Fritz, 2:260
- Strategic Defense Initiative (SDI), 3:12, 90, 239–240
- Strauss, Joseph, 2:274–276
- Strauss, Levi (1829–1902), 1:294; 2:15, 84–86

- Street lighting, 1:62
- Stuart, Gilbert, 1:10
- Studebaker Corporation, 2:182, 264
- Sturgeon, William, 1:199, 261
- Sturvaden, Clarence, 2:258
- Submarine, 1:154–155
- Submarine technology, 2:319–320
- Subway system of New York City, 2:242–243
- Sullivan, Louis, 2:174
- Sullivan, Thomas, 2:321, 322
- Sullivan, William, 2:176
- Superconductivity, 3:140–141
- Supersonic Pressure Tunnel, 3:73
- Suspension bridge, 1:155–157
- Sustainable agriculture, 3:240–242
- Sutherland, John Buie, 2:3, 125
- Swim fins, 1:62–63
- Swivel chair, 1:157–158
- Szilard, Leo, 2:201, 260, 296
- T-rail. *See* Railroad T-rail and tie
- Taft, Howard, 2:178
- Talbot, William Henry Fox, 2:32, 120
- Talking movies, 2:243–245
- Tampon, 2:320–321
- Tape measure, 2:146
- Tarrant, Robert, 2:114
- Tarter, Jill (1944–), 3:312–313
- Taussig, Helen (1898–1986), 3:141–143
- Taylor, Frederick (1856–1915), 2:146–147, 161, 170, 173
- TCP/IP (Transmission Control Protocol/Internet Protocol), 3:3, 107, 208, 300. *See also* Internet Protocol (IP); Transmission Control Protocol (TCP)
- Tea bag, 2:321–322
- Telegraph, 1:294–297
- Atlantic Telegraph Company, 1:226–227, 302
- invention of, 1:7, 226, 256, 260, 261–262, 236
- and Lincoln, Abraham, 1:257, 296, 310–311
- primary document: act authorizing construction of a transcontinental telegraph (1855), 1:297
- printing telegraph, 1:169, 271–272, 310
- Western Union Telegraph Company, 1:310–311
- Telenet, 3:3
- Telephone, 2:322–325
- first practical telephone credited to Bell, Alexander Graham, 2:5, 26–27, 322–325; 3:329
- mobile phone, 3:218–219
- touch-tone phones, 3:145
- Telephone switching, computerized, 3:143–144
- Television, 2:325–328
- Ten-Hour Movement, 1:297–299
- primary document: excerpt from preamble and constitution of the Lowell Female Labor Reform Association (1846), 1:298–299
- Tennessee Valley Authority Electricity Project (TVA), 2:328–329
- Terry, Eli, 1:74
- Tesla, Nikola (1856–1943), 2:9, 57, 58, 61, 62, 64, 147–149
- AC induction motor patented by, 2:10–12, 148–149
- biographical details, 2:147
- and Niagara Falls Power Plant, 2:107
- primary document: excerpt from commemoration address for Niagara Falls Power Plant, 2:108–112
- Thayer, Nathaniel, 1:178
- Thomas, David, 1:76
- Thomas, Valerie (1943–), 3:144
- Thomas, Vivien Theodore (1910–1985), 2:329–331
- Thomas de Colmar, Charles Xavier, 2:113
- Thompson, Benjamin (Count Rumford) (1753–1814), 1:158–159
- biographical details, 1:98, 158
- coffee percolator invented by, 1:98–99
- Rumford fireplace invented by, 1:141, 158–159
- Thompson, Ken (1943–), 3:313–316
- primary document: interview with Ken Thompson, inventor of UNIX (2011), 3:314–316
- Thompson Ramo Woolridge (TRW), 3:255
- Thoreau, Henry David, 1:46, 168
- Thornton, William, 1:304–305
- 3-D printing, 3:316–317
- as “additive manufacturing” (AM), 3:316
- bioprinting, 3:248, 317
- 3-D technology
- bioprinting, 3:248, 317
- Google Earth, 3:275
- and medicine, 3:250
- 3-D filmmaking, 3:248
- 3-D printing, 3:316–317
- 3-D television, 3:248
- Three-piece iron plow, 1:159–161
- primary document: petition to Congress for renewal of Jethro Wood’s patent (1846), 1:160–161
- Three-wheel clock, 1:63–64
- primary document: James Ferguson’s description of Benjamin Franklin’s three-wheel clock (1773), 1:64
- Tiananmen Square protests, 3:164
- Ticker tape, 2:149
- Tinsmiths, 1:222, 230. *See also* Iron- and silversmithing
- Tizard Mission, 2:331
- Tocqueville, Alexis de, 1:169
- Tom Thumb* locomotive, 1:7, 150, 289; 2:150–152
- primary document: John Latrobe’s description (1830), 2:150–152
- Toothpaste, 1:299–301
- TOR (The Onion Router), 3:318
- Torpedo, 1:301–302
- Torrey, John, 1:78
- Torvalds, Linus (1969–), 3:318–319

- Touch-tone phones, **3:145**
- Track-type tractor, **2:152**
- Traffic light, electric, **2:245–246**
- Trans-Alaska Pipeline, **3:145–147**
 - primary document: bill to reform the Trans-Alaska Pipeline System Authorization Act (1989), **3:146–147**
- Transatlantic cable, **1:302–303**
- Transcendental Movement, **1:168, 170–171**
- Transcontinental Railroad, **1:208–209, 258, 275, 288–289, 296; 2:3, 153–155**
- Transistor radio, **3:148–149**
- Transmission Control Protocol (TCP)
 - creation of, **3:3**
 - and early Internet, **3:208**
 - and packet switching, **3:17, 107**
 - TCP/IP, **3:3, 107, 208, 300**
- Transverse shuttle, **1:303**
- Tremblay, Bob, **3:24**
- Triangle Shirtwaist Factory Fire (1911), **2:5, 285**
- Trinity of personal computers, **3:223–224**
- Trinity test (first U.S. nuclear test), **2:260, 272, 297, 303**
- Triode tube, **2:24**
- Truman, Harry S., **2:303; 3:311**
 - and bombing of Hiroshima and Nagasaki, **2:260–261**
 - and creation of hydrogen bomb, **2:260, 283, 297; 3:89**
 - and National Science Foundation, **3:99**
- Trump, Donald, **3:278, 295, 323**
- Turbine engine, gas powered, **2:247**
- Turtle* submarine, **1:17–18, 65–66, 301**
 - action in American Revolution, **1:17–18, 65**
 - primary document: engraving of American *Turtle* (1775), **1:18**
 - primary document: letter from David Bushnell to Thomas Jefferson regarding experiments with submarines (1787), **1:66**
- TV dinner, **3:149**
- Twain, Mark, **2:1, 2**
- Twine knotter, **1:304**
- Twine self-binding harvester, **2:155**
- Twist drill, **1:304**
- Typewriter and QWERTY, **1:271; 2:155–156**
 - electric typewriters, **2:173; 3:61–62, 69**
 - and industrialization of leisure, **2:5**
- Tyson, Neil deGrasse (1958–), **3:319–321**
- UAVs. *See* Drones
- Unimate/industrial robot, **3:150**
- United States Capitol Building, construction of, **1:304–306**
 - design competition for, **1:304–305**
 - fire during War of 1812, **1:305**
 - rebuilding of, **1:305**
 - renovation (2013), **1:305–306**
- United States Constitution, **1:4, 25, 304–306**
 - commerce clause in, **1:139**
 - Constitutional Convention (1776), **1:53**
 - Constitutional Convention (1787), **1:26, 112, 136**
 - on copyright and patent law, **1:136**
 - on monopolies, **1:136**
 - Nineteenth Amendment, **1:309**
- United States Patent Board, **1:4, 107**
- United States Sanitary Commission (USSC), **1:187, 306–307**
- Universal Automatic Computer (UNIVAC), **3:1, 150–151**
 - and A-0 program, **3:1**
 - cost of, **3:151**
 - creation of, **3:65, 150–151**
 - purpose of, **3:69, 150**
 - size of, **3:151**
 - sold to U.S. Census Bureau, **3:151, 189**
- Unmanned aerial vehicles (UAVs). *See* Drones
- URL, **3:184, 208**
- Vaccines, **3:151–153**
 - eradication of smallpox, **3:135–136**
 - polio vaccine, **3:54, 118–119, 124, 125–126, 152**
 - smallpox inoculation, **1:56–59**
- Vail, Alfred, **1:7, 169, 260–262, 271–272, 295**
- Vapor-compression refrigerator, **1:161**
- Varmus, Harold Eliot, **3:261**
- Vaughan, Dorothy (1910–2008), **3:153–155**
- Vaux, Calvert, **2:6**
- Velocipede, **2:156–157**
- Venable, James, **1:178**
- Vending machine, **1:157–158**
- Vibrator, **2:158–159**
- Victor Adding Machine Company, **2:114**
- Victor Talking Machine Company, **2:29, 209–210, 117**
- Victoria, Queen
 - Eads, James B., recipient of Albert Medal of the Royal Society of Arts from, **2:143**
 - fan of carpet sweepers, **2:38**
 - first official telegraphic exchange from, **1:302**
 - phonograph message recorded by, **2:117**
- Victorian Era
 - and Central Park (New York City), **2:5–6**
 - and Columbian Exposition (1893, Chicago), **2:5–6**
 - corsets as erotica in, **1:212**
 - decorum in, **2:5–6**
 - labor relations in, **2:154**
 - time as commodity in, **2:5**
 - See also* Industrialism, Reconstruction, and the Gilded Age
- Vitrola. *See* Gramophone/Vitrola
- Video game, **3:321–323**
- Video streaming services, **3:323**
- Virtual reality (VR), **3:323–325**
- Vocoder, **3:155**

- Vogt, Peter K., 3:261
 Voight, Henry, 1:76
 Volwiler, Ernest H., 1:179
 Voyager spacecraft, 3:14, 16, 75, 96, 122, 127, 144, 156
 Vulcanization, 1:307–308
- Wadsworth, Augustus, 3:13
 Wagner, David, 3:32
 Wales, Jimmy, 3:250
 Walker, Mary (1832–1919), 1:308–309
 Waltham-Lowell textile system, 1:5, 61, 74, 128–130, 161–162, 297–298
 Wang, An (1920–1990), 3:325–326
 Washing machine, electric, 2:247–248
 Washington College, 1:253–254
 Washington, George
 almanacs used by, 1:12
 American Philosophical Society member, 1:8
 and American Revolution, 1:18, 116, 138
 and canal building project, 1:6, 95, 106–107
 Census Act (1790) signed by, 1:73
 forgiveness of Greene family's debts, 1:117
 glasses designed for by Franklin, Benjamin, 1:52
 innovation encouraged by, 1:74
 and National Road, 1:76, 132–133
 portraits of by Stuart, Gilbert, 1:10
 primary document: letter from Robert Fulton urging support of canal construction, 1:106–107
 primary document: order for all soldiers to receive smallpox inoculation, 1:58
 Rittenhouse, David, appointed as inaugural director of U.S. Mint by, 1:53
 on Turtle submarine, 1:66
 U.S. Capitol Building project begun by, 1:304–305
 Washington, Martha, 1:39, 101
 Water heater, 2:159–160
 Waterhouse, Benjamin, 1:45, 75
 Watson (computer), 3:191
 Watson, James, 3:5, 202
 Watson, Thomas, 2:26–27, 323; 3:68
 Watt, James, 1:107, 148, 151, 167, 289, 293, 143
 Weather Bureau, 2: 7–8
 Webster, Daniel, 1:233
 Webster, Noah, 1:135, 169
 Wedgwood, Thomas, 2:32
 Weinberg, Alvin M., 2:264–265; 3:104
 Welding, alternating current, 2:248–249
 Welding, automatic, 2:249
 Weller, Thomas H., 3:4
 Wells, Horace, 1:178
 Wells Fargo, 1:172; 3:307
 Welter, Barbara, 1:170
 Wescoff (Meltzer), Marilyn 3:1, 56
 Western Union Telegraph Company, 1:310–311
 Westinghouse, George, 2:3, 36, 160–161
 and gas transmission, 2:73
 and Niagara Falls Power Plant, 2:107–108, 110
 and railroad switch system, 2:127
 and Stanley, William, 2:9, 64
 support for alternating current (AC), 2:58, 62, 107, 148
 Westinghouse air brake, 2:160–161
 Wharton, John C., 2:45
 Wheel cipher, 1:162–163
 primary document: excerpts from Thomas Jefferson's notes on the wheel cipher (undated), 1:163
 White, Canvass, 1:76, 105
 White, Ellen, 1:236
 White, Lydia, 1:201
 “White out,” 3:61–62
 Whitney, Eli (1765–1825), 1:82, 163–166, 204
 cotton gin invented by, 1:5, 61, 86, 99–100, 117, 164
 and development of interchangeable parts, 1:74, 118–119, 131
 and development of milling machine, 1:130, 131, 164–165
 primary document: letter to his father regarding ginning of cotton (1793), 1:165–166
 Whiton, David Erskine (1825–1904), 1:67–68
 Wiley, Harvey, 2:136; 3:18
 Wilkins, Maurice, 3:5
 Willard, Emma, 1:170
 Willard, Simon, 1:87
 Williams, Roberta (1953–) and Ken (1954–), 3:327–328
 Wilson, Allen Benjamin, 1:283
 Wilson, James, 3:203
 Wilson, Joseph C., 3:158
 Wilson, Woodrow, 1:20, 283, 285; 2:163, 172, 223; 3:142
 Wilson Dam, 2:328
 Wind energy, 3:242–244
 Windmill. *See* Metal windmill
 Winthrop, John (1714–1779), 1:68–69
 primary document: observation of the planet Venus (1761), 1:69
 Wireless communication, 3:328–330
 Wise, Brownie (1913–1992), 3:157–158
 Women's Airforce Service Pilots (WASPs), 2:331–332
 authorized and overseen by Arnold, Hap, 2:261, 331–332
 and Avenger Field (World War II WASPs home), 2:261–262
 deactivation of, 2:262, 332
 merging of WAFS and WFTD to form WASP, 2:262, 332
 primary document: letters of Mary Anna Martin Wyall, WASP pilot trainee (1944), 2:262–263
 Women's Auxiliary Ferrying Squadron (WAFS), 2:261–262, 332
 Women's Flying Training Detachment (WFTD), 2:261–262, 332
 Wood, Carl, 3:70

- Wood, Jethro, **1**:160
- Wood, John C., **2**:183
- Woodbury, Robert, **1**:131
- Woodland, Norman, **3**:25–26
- Woodruff, Robert W., **2**:44
- Woodward, John, **2**:284
- World Wide Web. *See* Internet
- World's Columbian Exposition (1893, Chicago), **2**:58, 107, 162, 167
- AC generator and transformer at, **2**:58, 63, 107
- dishwashing machine at, **2**:4, 48–49
- Ferris wheel at, **2**:66, 67–68
- Kinematoscope at, **2**:6, 243
- refracting telescope at, **2**:167
- Rumford Kitchen at, **1**:141–142, 223; **2**:129
- zipper at, **1**:311
- World's Fairs, **1**:218, 224, 253; **2**:5–6, 66, 161–164, 253; **3**:28, 57–58, 145, 155
- female participation in, **2**:4, 193
- history of, **2**:161–164
- IBM pavilion at 1964 World's Fair, **3**:68
- Louisiana Purchase Exposition (1904, St. Louis), **2**:45, 67, 162–163, 187
- Philadelphia Centennial Exposition (1876), **2**:112, 134, 161
- See also* Great Exhibition of 1851 (London); World's Columbian Exposition (1893, Chicago)
- Wozniak, Steve (1950–), **3**:158, 177–180, 209, 223, 244–245
- Wright, Wilbur (1867–1912) and Orville (1871–1948), **2**:164–166, 223
- first powered, controlled aircraft, **2**:7, 164–166, 170–171, 178, 312
- primary document: entry from Orville Wright's diary, **2**:166
- Wu, Chien-Shiung (1912–1997), **2**:333–334
- Wyll, Mary Anna Martin, **2**:262–263
- Xerox Corporation, **3**:132, 158–160, 190, 214–215, 264, 292
- primary document: patent for xerography (1956), **3**:159–160
- Y2K, **3**:169
- Yale, Linus Jr., **1**:216
- Yalow, Rosalyn Sussman (1921–2011), **3**:160–162
- Yerkes, Charles Tyson, **2**:67, 167
- Yerkes Observatory, **2**:166–168
- YouTube, **3**:330
- Zipper, **1**:311